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CONTRACT AND SCREW TRIALS OF THE U. S. S. *KATAHDIN.*

BY PASSED ASSISTANT ENGINEER F. C. BIEG, U. S. NAVY.

The official trial of this harbor defense ram took place in Long Island Sound on October 31, 1895, and consisted of two runs over a measured course of seventeen nautical miles, the turn at the end of the first run being made at full speed. The mean speed for the trial, with a small tidal correction applied, was 16.1146 knots. Although the contract speed of 17 knots was not attained, the *Katahdin* is still, in the writer's opinion, a formidable vessel, and the Navy has acquired, by the Act of Congress, approved January 4, 1896, and the Navy Department's order of January 10, a valuable fighting machine. The views of the Navy Department in regard to the *Katahdin* are expressed in the following letter written by the Secretary of the Navy to Senator Eugene Hale, who introduced the resolution authorizing the acceptance of the vessel:

"NAVY DEPARTMENT,

"WASHINGTON, D. C., *December 23, 1895.*

"* * * In answer to your request 'for information as to the grounds which prevented the acceptance of the ram by the

Department and a statement of the facts as to the manner of construction, and whether the ram does not furnish to all intents and purposes a substantial compliance with the contract, and whether in your (my) judgment it is not desirable that the ram be accepted and put upon the list of commissioned vessels of the United States Navy,' I have to state as follows:

"The ship is well built and has been completed in accordance with the contract save in a few minor particulars, and is a desirable vessel for the Navy, being designed for harbor defense. The construction of the *Katahdin* was authorized as an experiment, and inasmuch as the proper method of applying the principles of naval architecture to a vessel of her type had never been demonstrated, the results that would be obtained were by no means ascertainable, and it was, therefore, largely conjectural as to what performance she would be capable of. The Bath Iron Works accepted the contract for this vessel upon faith in the Department's designs of hull and machinery; they complied with the letter of the contract and endeavored in good faith to carry out the desires of the Department in regard to particulars that had not been fully prescribed. They performed their part of the undertaking in the most satisfactory manner and did everything that it was possible to do to make the vessel fulfill the purposes of Congress in authorizing her construction and prove successful and efficient. Their success is evidenced by the fact that the power which the engines were designed to develop was exceeded, but it seems that the good workmanship applied on the hull could not offset the resistance to be met with on account of the peculiar lines of this type of vessel, and her failure to develop the required speed can in no wise be attributed to fault on the part of the contractors. Owing to the way the ram behaved on the trial when her engines were exerting their full power, the Department is of opinion that it would probably be impossible to make a ship of this kind run at 17 knots an hour with engines of any horse power that could be put into her.

"The vessel was sent to the navy yard, New York, to remain there at the risk and expense of the contractors until the ques-

tion as to her acceptance should be decided, and she is still at that yard.

"The Department recommends that it be given authority to accept the vessel under the contract for her construction, the contractors to make good all uncompleted work necessary to put the vessel in the condition required by the contract. * * *

"H. A. HERBERT, *Secretary.*"

"Hon. EUGENE HALE,
United States Senate."

The contract for this vessel, first officially known as *Harbor-Defense Ram No. 1*, was let to the Bath Iron Works of Bath, Maine, on January 28, 1891, on plans and specifications furnished by the Navy Department. The contract price for the vessel complete was $930,000. The *Katahdin* was built under the Act approved March 2, 1889, which authorized the construction of a harbor defense ram of the general type approved by the Naval Advisory Board in 1881, this general type being based on the designs of Rear Admiral Daniel Ammen, U. S. Navy. She was launched on February 4, 1893.

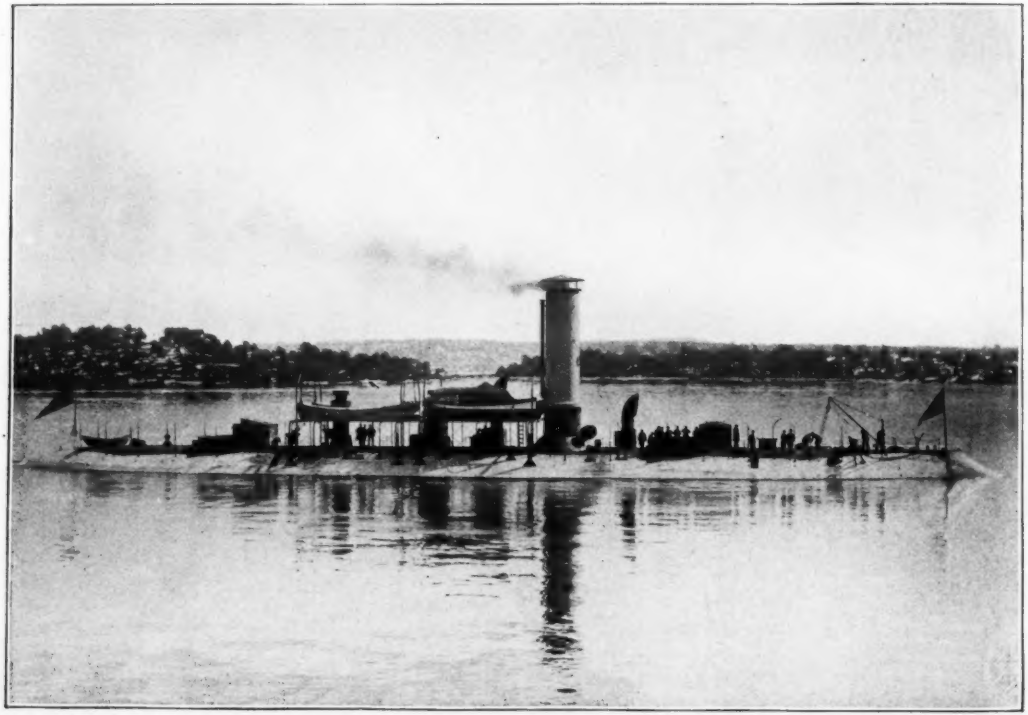
The vessel is constructed entirely of mild steel, and is designed upon the longitudinal and bracket system, with an inner bottom extending from the collision bulkhead to the stern. The longitudinals and girders supporting the deck are continuous, converging to the stem casting and to the stern, the frames and beams being intercostal. The depth of longitudinals and vertical keel throughout their length is 24 inches, and of the girders supporting the armored deck, 15 inches. The vertical keel, two longitudinals, and armor shelf on each side of the vertical keel are water tight, forming transversely 6 compartments, these being divided longitudinally by water tight frames. By this means the space between the inner and outer skin is subdivided into 72 compartments. The transverse and longitudinal bulkheads between inner skin and deck armor divide this space into 30 compartments, making a total of 102 compartments in the vessel. The vessel is provided with a removable wrought-steel ram head, accurately fitted and securely held in position in the cast-steel stem.

Scantling.—The inner keel is 17½ pounds, the outer keel 20 pounds per square foot; the vertical keel 17½ pounds, with two angles 3½ by 3 inches of 8 pounds per foot at the top and two angles 4 by 3 inches of 9 pounds per foot at the bottom, connecting it with the flat keel plates. The flat keelson plates are 15 pounds per square foot, the outside plating 15 pounds and the inner plating 10 pounds per square foot. The plates of the longitudinals are 15 pounds per square foot for the water tight spaces, and 12½ pounds per square foot for the remainder. Angles at top and bottom of these longitudinals are 3 by 3 inches of 7 pounds per foot. The main frame angles are 3½ by 3 inches of 8 pounds per foot and the reverse angles, 3 by 3 inches of 7 pounds per foot. Angles to water tight frames are 3 by 3 inches of 7 pounds per foot. Floor plates to water tight frames are 10 pounds per square foot; all others, 12½ pounds per square foot. The bulkhead plates of 10 pounds per square foot are stiffened by angles 3 by 2½ inches of 6 pounds per foot.

Quarters for Officers and Crew.—The wardroom, into which open seven state rooms and a pantry, is on the after berth deck, one compartment abaft the engine room bulkhead; abaft the officers' quarters is the steering room and a berthing space for a portion of the crew, the forward deck and the compartment just abaft the engine room being designed entirely for the crew. Communication between the two ends of the vessel is by means of a wing passage on each side of the machinery spaces.

Drainage System.—The drainage system is so arranged that any compartment can be pumped out by the steam pumps. The vessel can be submerged to fighting trim by means of fourteen 8-inch Kingston valves, one in each transverse water-tight compartment of the double bottom. Sluice valves are fitted in the vertical keel and the water tight longitudinals in these compartments.

The only projections above the armor deck are the conning tower, smoke pipe ventilators, hatch coamings, and skid beams upon which the boats are supported, and a light mast for signalling purposes.



U. S. S. "KATAHDIN."

SUMMARY OF HULL DATA.

Length over all, feet	251
Length on load water line, feet and inches	250–2
Beam, extreme, feet and inches	43–5
at L. W. L., feet and inches	41–8
Draught, mean, normal, feet	15
Area immersed midship section, square feet	478.2
Displacement at load draught, tons	2155
Tons, per inch	19 16
Center of buoyancy above base line, feet and inches	9–4½
Center of buoyancy forward of midship section, inch	⅜
Center of gravity above base line, feet and inches	13–0¼
Transverse metacenter above C. B., feet and inches	11–10½
Longitudinal metacenter above C. B., feet and inches	393–7⅛
Distance from center of gravity to transverse metacenter, feet and inches	8–3¼
Distance from center of gravity to longitudinal metacenter, feet	390
Coefficient of displacement	0.461
Coefficient of midship section	0 734
Coefficient of L. W. L.	0.739
Cylindrical coefficient	0.617
Area of L. W. L. plane, square feet	8,037
Wetted surface, square feet	10,787
Bunker capacity, tons	236.88

Armor.—All of the armor is of nickel steel. The outside strake of the deck armor is 6 inches thick, the next strake inboard tapers in thickness in its breadth from 5½ inches to 2½ inches, the remainder of the deck plating being 2½ inches in thickness, including the lower course of plating. The side armor is two strakes in depth, the upper 6 inches and the lower 3 inches thick, secured by bolts with counter-sunk heads driven from the outside through wood backing of yellow pine, and two backing plates, each 20 pounds per square foot, and set up with nuts on rubber washers. All hatches through the armored deck have battle plates. The smoke pipe and ventilators have inclined armor 6 inches thick. The conning tower is 18 inches thick.

Armament.—The vessel has no armament and is to rely entirely upon ramming for her offensive power. She is, however, fitted with four 6-pounder rapid-fire guns, two forward and two aft in the coaming around the hatches, for use against torpedo boat attack.

Main Engines.—The propelling engines are placed in water-

tight compartments and separated by an athwart-ship bulkhead fitted with a water tight door. The forward engine turns the port and the after one the starboard propeller. They are of the horizontal, direct-acting, triple-expansion type, each with three cylinders. They were designed for a collective indicated horse-power of propelling, air pump and circulating pump engines of 4,800 with about 150 revolutions per minute. The high pressure cylinder of the after or starbord engine is forward, and is aft on the forward or port engine.

The cylinders consist of castings, $1\frac{1}{8}$ inches thick, of best quality of cast iron, with working linings for the cylinders and valve chests. The cylinder casings include the valve chests, steam-ports and passages, the inboard heads, and the various brackets to which the braces are attached, and by which the cylinders are secured to each other and to the engine keelsons.

The linings are of close-grained cast iron, as hard as could be properly worked, each having a bearing at about the middle of its length and at each end. The linings, after being secured in place in the casings, were accurately bored to diameters of 25, 36 and 56 inches for the high, intermediate and low pressure cylinders, respectively, and to a thickness of 1 inch, the boring being done with the cylinders in a horizontal position. They are counterbored at the inboard ends $\frac{3}{4}$ of an inch.

The centers of the high and intermediate pressure cylinders are 4 feet $\frac{5}{8}$ inch apart, and those of the intermediate and low pressure cylinders, 6 feet 1 inch apart, with the cylinder axes all in one plane and parallel.

The main valves are of cast iron, of the piston type, and worked by Marshall valve gear, there being one valve for each high and each intermediate pressure cylinder, and two for each low pressure cylinder. The valve gear, except rock shafts, is interchangeable, and is so adjusted that the mean cut-off in full gear for both ends of each cylinder is at 0.7 stroke.

The reversing gear consists of the usual steam cylinder and a hydraulic controlling cylinder, the piston rods of both fitted to the same crosshead, and the ends of the hydraulic cylinder connected with a by-pass worked from the stem of the steam start-

ing valve. These valves receive their primary motion from a hand lever at the starting platform, and are stopped by a system of levers receiving motion from a pin on the reversing arm, the parts being so adjusted in this system that the reversing engine follows the motion of the hand lever, and when stopped is firmly held by the controlling cylinder. There is also a small hydraulic pump for reversing by hand.

Each engine has a 9-inch balanced stop valve and swing throttle valve placed in the same casing, the swing throttle valve being next the high pressure cylinder casing and bolted to it. The throttle valve is worked by a lever at the working platform and has an index to show the position of the valve.

The main pistons are of cast steel and dished, and each has two cast-iron packing rings $\frac{3}{4}$ inch wide and $\frac{1}{4}$ inch thick, set out by steel U-springs. The piston rods (one for each piston) and the connecting rods are of forged steel. The connecting rods are 72 inches long between centers, turned 5 inches in diameter at small end and 7 inches at large end, the sides being faced off to a uniform thickness of $5\frac{1}{4}$ inches. The crossheads are of cast steel with pins $5\frac{1}{4}$ inches in diameter and $6\frac{3}{4}$ inches long. Each crosshead has wearing slippers and brasses working on a bar guide. The slippers are of composition, the brasses and slippers being faced with white metal.

The bed plates, which consist each of two gun-iron castings well stiffened by ribs, are secured to the keelsons by body-bound $1\frac{1}{4}$-inch steel bolts. The cylinders are secured together by forged steel tie rods and supported on wrought-steel keelson plates built in the vessel.

The exhaust system, between the valve chests of each engine, consists of one 11-inch copper pipe with two 11-inch branches leading from the high to the intermediate valve chests; one 15-inch copper pipe, with two 15-inch branches from the intermediate to the low pressure valve chests; and a $19\frac{1}{2}$-inch copper pipe connecting the low pressure valve chests with the condenser.

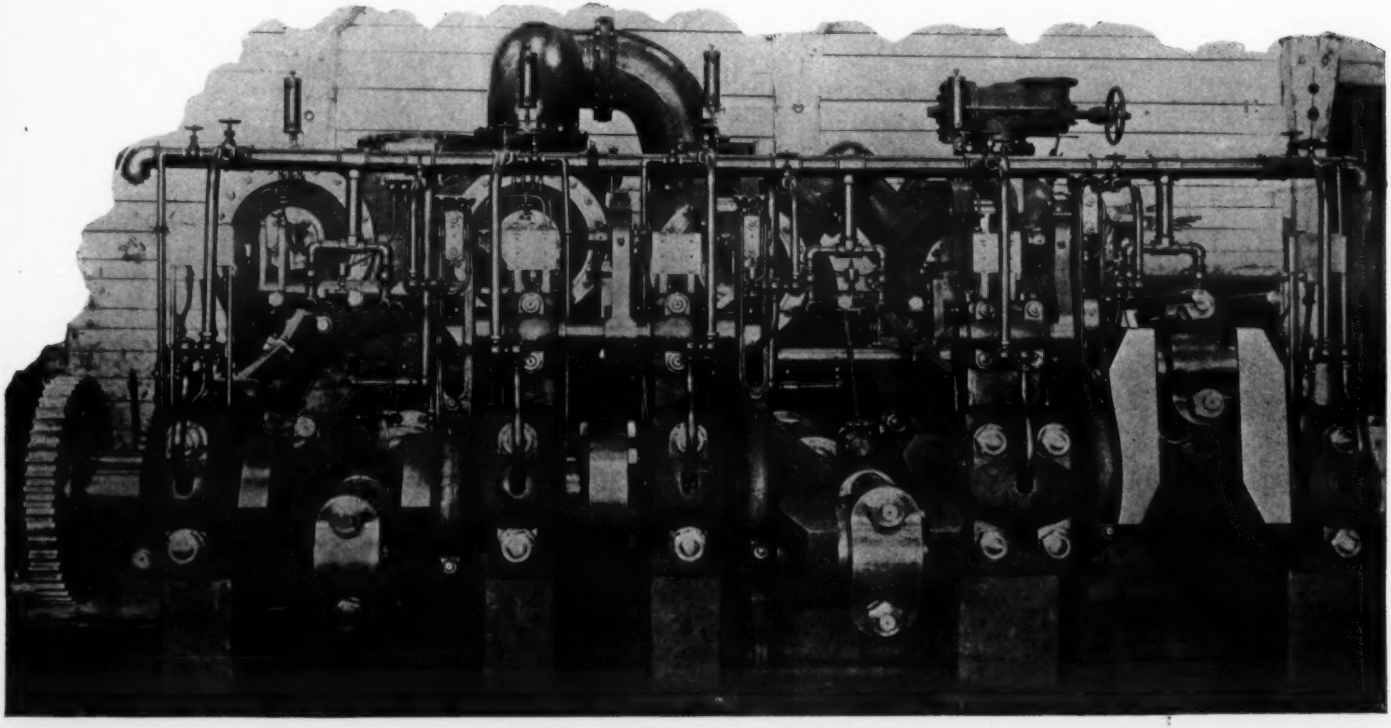
All the crank, line, thrust and propeller shafts are of forged steel. Each length is forged solid in one piece, and has a hole

drilled axially through it from end to end. Each crank shaft is in two sections, the throw of the cranks being 18 inches. The coupling discs are $2\frac{3}{4}$ inches thick and 21 inches in diameter. The length of the section of shaft for the high and intermediate pressure engines is 10 feet $1\frac{3}{4}$ inches, and for the low pressure engine, 6 feet $2\frac{1}{2}$ inches. The journals on each section of shafting are $10\frac{3}{4}$ inches in diameter and 13 inches long, with the exception of the journal between the high and intermediate pressure cylinders, which is 18 inches long. The crank pins are 11 inches in diameter and 12 inches long. The crank webs are each $12\frac{1}{2}$ inches wide and 7 inches thick. There is a hole 5 inches in diameter bored axially through each crank shaft and pin. The cranks of each engine are bolted together at angles of 120° to each other, the sequence being high, intermediate and low pressure. The various lengths of the crank shafts are coupled to each other by forged steel bolts, with wrought-iron nuts and split pins. The seatings for eccentrics are forged on the shaft, and are 1 inch larger in diameter.

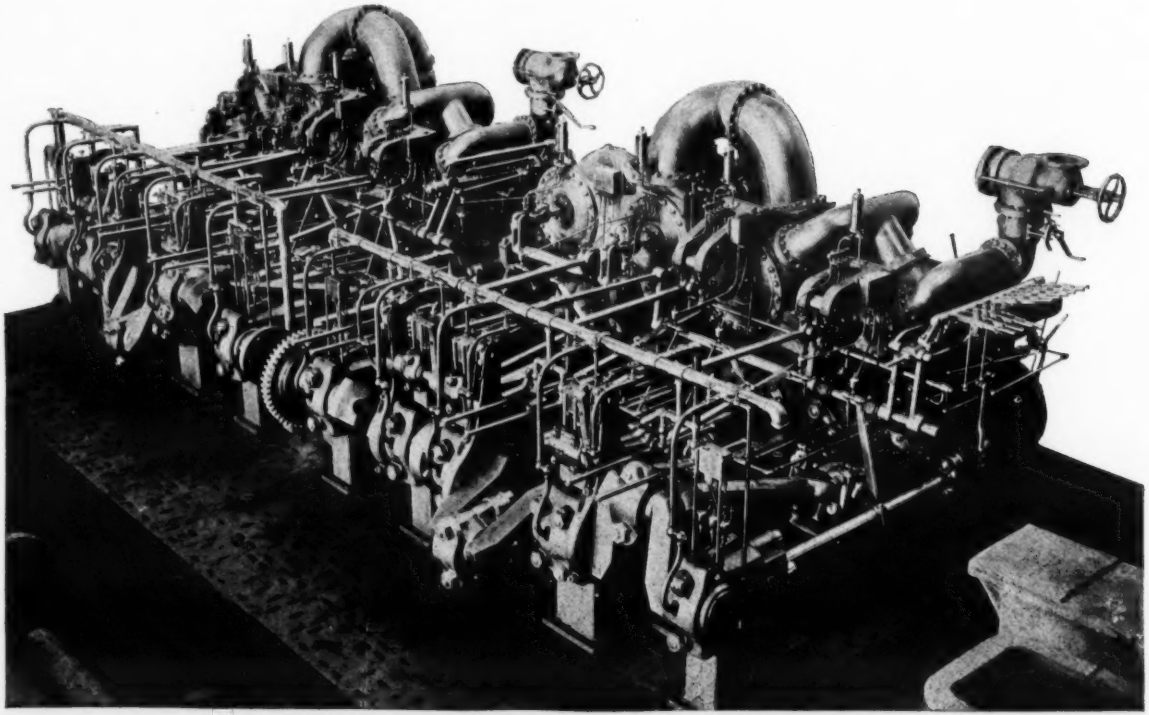
The line shaft of each engine is $10\frac{1}{2}$ inches in diameter, 19 feet 1 inch over all, and has a 5-inch axial hole. There is a coupling disc forged on each end, 21 inches diameter and $2\frac{3}{4}$ inches thick.

The thrust shaft is $10\frac{1}{2}$ inches in diameter, 8 feet 1 inch long over all, with a 5-inch axial hole. Each shaft has 10 thrust collars $1\frac{1}{4}$ inches wide, with spaces of 2 inches, the collars being 14 inches outside diameter. There is a coupling disc forged on the forward end, $2\frac{3}{4}$ inches thick and 21 inches in diameter. The coupling at the after end is forged to fit the coupling on the forward end of the propeller shaft.

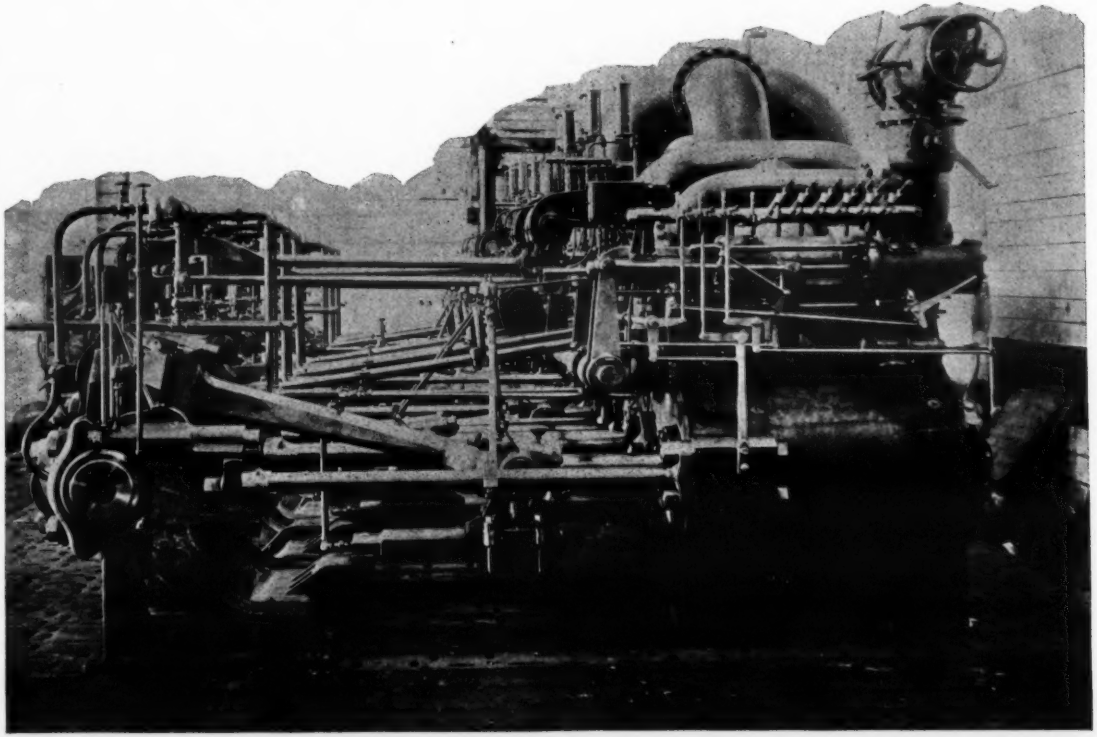
The propeller shafts are each in two sections, the forward section being $10\frac{1}{2}$ inches in diameter and 29 feet 5 inches long over all, and the after section, 11 inches in diameter and 20 feet 6 inches long over all. The 5-inch axial hole is tapered where it passes through the propeller hub. The forward section is fitted with a composition casing, shrunk and pinned on, $\frac{3}{4}$ of an inch thick where it runs in the bearings and $\frac{1}{2}$ inch elsewhere, and perfectly water tight; the joints lap over each other 1 inch. The forward and after ends of the casing are chamfered, and the



STARBOARD ENGINE U. S. S. "KATAHDIN."



STARBOARD ENGINE U. S. S. "KATAHDIN."



STARBOARD ENGINE U. S. S. "KATAHDIN."

shaft at the after end of the casing is protected by a fillet of soft solder. The inboard ends of the forward section are fitted with separate forged steel coupling discs, so that the shafts may be withdrawn from outboard. The after ends of the forward sections and the forward ends of the after sections have solid forged coupling discs covered with a water tight casing. The after section is cased with composition, ¾ inch thick where it passes through the outboard bearing, the casing being in one length, shrunk and pinned on. The shaft is protected at the forward end of the casing by a fillet of soft solder, the after end of the casing making a water tight joint with the propeller hub.

The line shaft bearings are of cast iron fitted with bottom brasses lined with white metal. The thrust bearing is of cast iron, with white metal linings. The cap is similarly fitted. The body of the bearing forms a trough, from which an oil hole leads to each collar and each recess, the white metal being properly channeled for distribution of oil. All the bearing recesses are connected at the bottom by holes.

At each end of each thrust bearing there is a divided stuffing box and gland to prevent escape of oil. A cooling coil, connected with the engine room water service, keeps the liquid in the trough cool. Inside of the trough, just forward and abaft of the thrust collars, are composition bearings capable of vertical adjustment to take the weight of the shaft from the thrust collars. The caps of these bearings are of cast iron lined with white metal. There are four adjusting screws, two at each end of the thrust bearing pedestal, for adjusting the bearing fore and aft.

Each stern tube is finished as follows: There are two shaft bearings, 4½ feet long, one at each end, of mild steel with internal cast steel rings. Fitted to these rings are composition bushings, made in halves, fitted with sections of lignum vitæ on end of grain and bored to a loose fit on the shaft casing. The usual stuffing box is fitted at the forward end. Lignum vitæ is fitted in the stern bracket bearings as in the stern tubes. A cast-steel sleeve is secured to each stern bracket to form a fair water line to the propeller boss.

Screw Propellers —They are three-bladed, of manganese bronze,

the starboard propeller being right and the port one left handed. The diameter of each is 11 feet 10 inches, pitch 14 feet, disc area 109.98 square feet, and the helicoidal area 36 square feet. Each boss is accurately bored to fit the taper on after end of shaft and fitted with two feather keys, and held on the shaft by a nut screwed on and locked in place.

Main Condenser.—There is one main condenser in each engine room, with shells of cast composition, 4 feet 11 inches in internal diameter and $\frac{7}{16}$ inch thick. The circulating water passes through the tubes. There are 2,911 seamless drawn brass tubes in each condenser, $\frac{5}{8}$ inch outside diameter, No. 20 B. W. G. in thickness, and packed with cotton tape by screw glands beaded at their outer ends; they are 7 feet long between tube sheets, and spaced $1\frac{5}{16}$ inch between centers.

The cooling surface of each condenser is 3,334 square feet, measured on the outside of the tubes. The ratio of the cooling surface of both main condensers to total heating surface is 1 to 1.82.

Air and Circulating Pumps.—There is one combined air and circulating pump of the Blake type for each condenser. It has two vertical single acting air pumps, 25 inches in diameter and 12 inches stroke, and one horizontal double acting circulating pump, 31 inches in diameter and 18 inches stroke, all worked by a horizontal steam cylinder, 18 inches in diameter and 18 inches stroke, the circulating pump being worked direct and the air pumps by vibrating beams. Each circulating pump is capable of discharging 4,800 gallons of water per minute from the bilge, the openings for sea and bilge suction being each 11 inches in diameter. The stop valves in these suction pipes are so connected by a locking device that when one is open the other is shut.

Auxiliary Condensers.—There is in each engine room an auxiliary condenser with a cooling surface of 202 square feet, of sufficient capacity for one-half the auxiliary machinery. The combined air and circulating pump of each auxiliary condenser is of the Blake type, with one circulating and two air pump cylinders,

8 inches in diameter and 8 inches stroke, the steam cylinder being 6½ inches in diameter and 8 inches stroke.

Feed Tanks.—There is a feed tank in each engine room, each having a capacity of about 500 gallons. A portion of the tank is fitted as a filter.

Auxiliary Pumps.—There are in each engine room the following auxiliary pumps: One auxiliary feed, fire and bilge pump, described under feed pumps; one vertical duplex Blake pump, with steam cylinders 10 inches and water cylinders 6 inches in diameter, and a stroke of 12 inches, arranged to draw from the sea or bilge or to deliver into the fire main or overboard; one vertical duplex Blake pump, with steam cylinders 7½ inches and water cylinders 4½ inches in diameter, and a stroke of 8 inches arranged to draw from the sea only and deliver into the fire main and water service pipes. These pumps can all be used as fire pumps with steam of 60 pounds pressure.

Boilers.—There are two double-ended and one single-ended horizontal, return fire tube boilers, all of open hearth steel, 13 feet 8¼ inches in outside diameter, with a total heating surface of 12,150 square feet and a grate surface of 354 square feet. The double-ended boilers are 22 feet 6 inches, and the single-ended, 11 feet 7¼ inches long. Each boiler has three corrugated furnace flues, 3 feet 6 inches in least internal diameter, and $\frac{9}{16}$ inch thick. The boiler shells are 1½-inches thick. The upper plate of each head of the boilers is curved back to a radius of 3 feet 3 inches, the heads being flanged outwardly at the furnaces and inwardly at the circumference. The two plates forming the head are welded together. The longitudinal joints of boiler shells are butted with ⅞-inch straps inside and outside, treble riveted, and break joints. Joints of heads with shells are double riveted, except the curved portions, which are treble riveted; all other circumferential joints are lapped and treble riveted. Joints in furnaces and combustion chambers are single riveted.

The tubes are of steel, lap welded, all 2¼ inches outside diameter, spaced 3¼ inches from center to center vertically and 3½ inches horizontally. The ordinary tubes are No. 12 B.W.G. in thickness and are swelled to $2\frac{5}{16}$ inches external diameter at the

front ends. The front ends are expanded in the tube sheet and beaded over into a counter bore, which is filled with a ring. The stay tubes are No. 6 B.W.G. in thickness, reinforced at both ends to an external diameter of $2\frac{3}{8}$ inches, leaving the bore of the tube uniform from end to end. They are swelled at the front ends to $2\frac{1}{2}$ inches external diameter. They are threaded parallel at combustion chamber ends and taper at front ends to fit the threads in tube sheets. They are screwed into the tube sheets to a tight joint at the front ends, and made tight at the back ends by expanding and beading. Cast-iron ferrules of $1\frac{1}{2}$ inches internal diameter are used to protect the ends of stay tubes in combustion chambers. The grate bars are of the ordinary type and of cast iron. Sectional steel circulating plates are supported from the stay tubes and can be easily introduced or removed through the man holes.

The top of the smoke pipe is 52 feet 9 inches above the lowest grates, the area of the pipe being 50.26 square feet. The uptakes are separate and all below the armor bars.

BOILERS.

Steam pressure, pounds	160
Length, double ended, feet and inches	22–6
single-ended, feet and inches	11–$7\frac{1}{4}$
Diameter, feet and inches	13–$8\frac{1}{4}$
Thickness of shell plates, inches	$1\frac{1}{8}$
top heads, inches	2
tube sheets, inch	$\frac{3}{4}$
back heads, single-ended, inch	$\frac{3}{4}$
butt straps, inch	$\frac{7}{8}$
combustion chamber sheets, inch	$\frac{1}{2}$
Rivets, diameter for circumferential seams, inches	$1\frac{1}{16}$ and $1\frac{1}{4}$
longitudinal seams, inches	$1\frac{1}{8}$
combustion chamber sheets, inch	$\frac{15}{16}$
Braces above tubes, diameter, inches	$2\frac{1}{4}$
to back tube sheet, diameter, inches	2
around lower man-holes	2
Screw stays of combustion chamber backs, diameter, inches	$1\frac{1}{4}$
pitch, inches	7×7
Furnaces, inside diameter, inches	42
outside diameter, inches	$46\frac{1}{4}$
thickness, inch	$\frac{9}{16}$

Furnaces, number in each double-ended	6
in the single-ended	3
total	15
Grates, length, feet and inches	6–9
Combustion chambers, number in each double-ended	6
number in the single-ended	3
Tubes, plain, number in each double-ended	648
number in the single-ended	324
outside diameter, inches	2¼
stay, number in each double ended	180
number in the single-ended	90
outside diameter, inches	2¼
mean length between tube sheets, feet and inches	7–10½
spacing, horizontally, inches	3½
vertically, inches	3½
total number in each double-ended	828
total number in each single-ended	414
Heating surface, plate, each double-ended, square feet	960
plate, each single-ended, square feet	480
tube, each double-ended, square feet	3,900
tube, each single-ended, square feet	1,950
total, each double-ended, square feet	4,860
total, each single-ended, square feet	2,430
total, all boilers, square feet	12,150
Grate surface, each double-ended, square feet	141.6
each single-ended, square feet	70 8
total, square feet	354.
Ratio total heating to grate surface	31.5 to 1
Safety valves, number, each double-ended	2
number, each single-ended	2
diameter, inches	3½
load on, pounds per square inch	160

Forced Draft.—Air pressure is maintained in the fire rooms by four blowers—two for each air tight fire room,—the engines having two cylinders 5 inches in diameter by 4 inches stroke. The fans are 45 inches in diameter, direct connected, and deliver directly into the fire rooms, except that light iron baffle plates are fitted to prevent the blowing about of coal dust.

Steam Piping.—The main steam pipes are of No. 4 B.W.G. copper, 9 inches in diameter. The auxiliary steam piping, 5 inches in diameter and of No. 6 B.W.G. copper, extends throughout the engine and boiler spaces, with connections to all auxiliary machinery therein, and additional branches to the windlass, and

steering engines. This pipe connects with the auxiliary stop valves of all boilers, and with the main steam pipe in each engine room. Stop valves are also fitted wherever the system cuts a transverse water tight bulkhead. All downward branches are fitted with stop valves close to the auxiliary steam pipe to prevent accumulation of condensed water while the branch is idle, all condensation in the auxiliary steam pipe proper draining into the separator traps. There is a separate auxiliary steam pipe connecting the dynamo engines with the boilers.

Feed Pumps.—There is one main and one auxiliary feed pump in each fire room. Two of these are horizontal and the remaining two vertical, duplex pumps of the Blake pattern, with steam cylinders 7½ inches, water cylinders 4½ inches in diameter and a stroke of 8 inches. The main feed pumps draw from the feed tanks only and deliver into the main feed pipe only. The auxiliary feed pumps can draw from the sea, feed tanks, bilge or boilers and deliver into the auxiliary feed pipe, fire main or directly overboard.

In each engine room there is an auxiliary pump of the same type as above, but with steam cylinders 10 inches and water cylinders 6 inches in diameter and a stroke of 12 inches. These pumps can draw from the sea, the bilge abaft the engine rooms, the secondary drain pipe, the drainage cistern and the feed tanks, and deliver into the main or auxiliary feed pipes, the fire main or overboard. When used as fire pumps, they can be worked with steam of 60 pounds pressure.

Distilling Plant.—This consists of two evaporators and two distillers with a combined capacity of 3,000 gallons of potable water per day. For the distillers there is one horizontal Davidson circulating pump, with steam cylinders 5½ inches and water cylinders 6 inches in diameter and a stroke of 10 inches. The fresh water is pumped into the tanks forward by a small pump, fitted with a meter and a pipe leading from the atmosphere above the ship's awnings to the suction of this pump, with a regulating valve, so that air can be forced into the tanks with the water. For the evaporators there is a small pump for feeding, and another for drawing off the fresh water and delivering it into the auxiliary

feed pipes. The evaporators are of the improved Baird type, horizontal, the shells being of plate steel, lapped and riveted, the heads and flanges of composition and the coils of copper, tinned inside and out. The distillers are of cast iron ¾ inch thick, with tinned copper coils, fitted with filters, and with the parts accessible for cleaning and repairs.

Dynamos.—There are two Thomson-Houston dynamos, each of 50 amperes and 80 volts, and driven by double engines of the vertical, inverted, direct acting type, with cylinders 5 inches in diameter and a stroke of 3 inches.

Ventilation.—A Sturtevant fan, with a capacity of at least 12,000 cubic feet of air per minute, is fitted in each engine room. Each fan is driven by an independent engine of the same kind as described under the forced draft blowers.

The foul air is exhausted from all parts of the vessel by means of the blowers in the engine and fire rooms; fresh air is supplied from the main ventilator through air ducts led along the under side of deck forward and aft.

An ash hoisting engine is fitted in each fire room of sufficient power to hoist 300 pounds from the fire-room floor to the deck in five seconds with steam of 60 pounds pressure.

The vessel is fitted with a Williamson's steam steering gear, located in the compartment just abaft the wardroom.

THE TRIAL.

On October 29, the contractors made a short preliminary run. On October 31, the vessel left New London, Conn., at 7 A. M., the hull being clean, and the mean draught, fifteen feet. The weather was then fine, with a moderate breeze from the eastward. The course of seventeen nautical miles lay near the Long Island side of the Sound, its eastern end being about 38 nautical miles from New London, and its direction almost east and west. Just after crossing the first line, a small set screw in the valve gear of the starboard air pump broke, stopping the pump and necessarily the starboard engine. The vessel kept on with the port screw, making a turn back, so that when the damage had been repaired, she was ready to start again and crossed the first line at 11·48.02 A. M.

The run west was made in 1 hour 55 minutes and 83 seconds, and the run east, in 1 hour 0 minutes and 44 seconds, making the total time for the two runs, 2 hours 6 minutes and 17 seconds. The tidal correction applied to the trial course of 34 miles made the distance run through the water 33.91683 nautical miles. This distance, covered in the time given above, gave a mean speed of 16.1146 knots. The wind during both runs was easterly, varying from 3 to 5 (Beaufort scale), being stronger during the return run. There was a moderate surface sea, but neither the pitching nor rolling of the vessel was appreciable.

While making the steering tests immediately after the end of the trial, the helm was put over from hard-a-starboard to hard-a-port in 17 seconds, the vessel being under full speed and the greatest angle of heel being about 1½ degrees. There was no vibration at full speed, and the vessel turned readily and quickly.

The machinery worked well and with no vibration except a slight one in the valve gear. No water was used on any journals, except where running through the hollow bearings. Only one feed pump, one water service pump and one bilge pump were in use.

While crossing the Sound on her return to New London, the wind blowing half a gale, a moderate sea was encountered. The vessel rolled slightly and easily, the sea breaking completely over the hull. The draught on reaching New London was 14 feet 8½ inches.

DATA OF TRIAL.

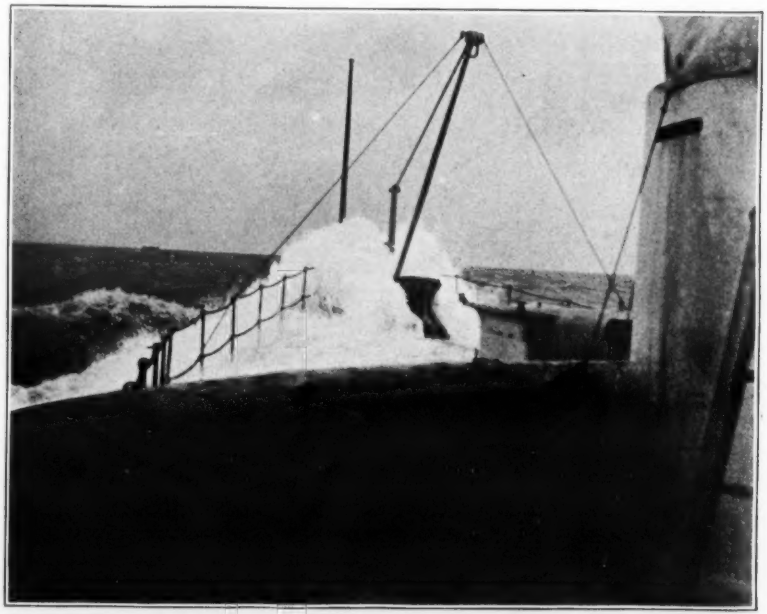
Mean draught, forward, feet and inches	14–4
Mean draught, aft, feet and inches	15–4½
Draught, mean, feet and inches	14–10¼
Displacement, mean, tons	2,125
Midship section area, square feet	461
Average speed, knots	16.1146
Speed^3 × area immersed midship section ÷ I.HP.	392 94
Speed^3 × displacement^{⅔} ÷ I.H.P.	140.88

SYNOPSIS OF STEAM LOG.

	Starboard.		*Port.*
Revolutions of main engines per minute	147.72		143.71
Revolutions of main engines, mean		145.715	
Piston speed, feet per minute	886.32		862.26

U. S. S. "KATAHDIN" ON TRIAL.

PHOTOGRAPH BY F. V. MOODY, BATH, ME.



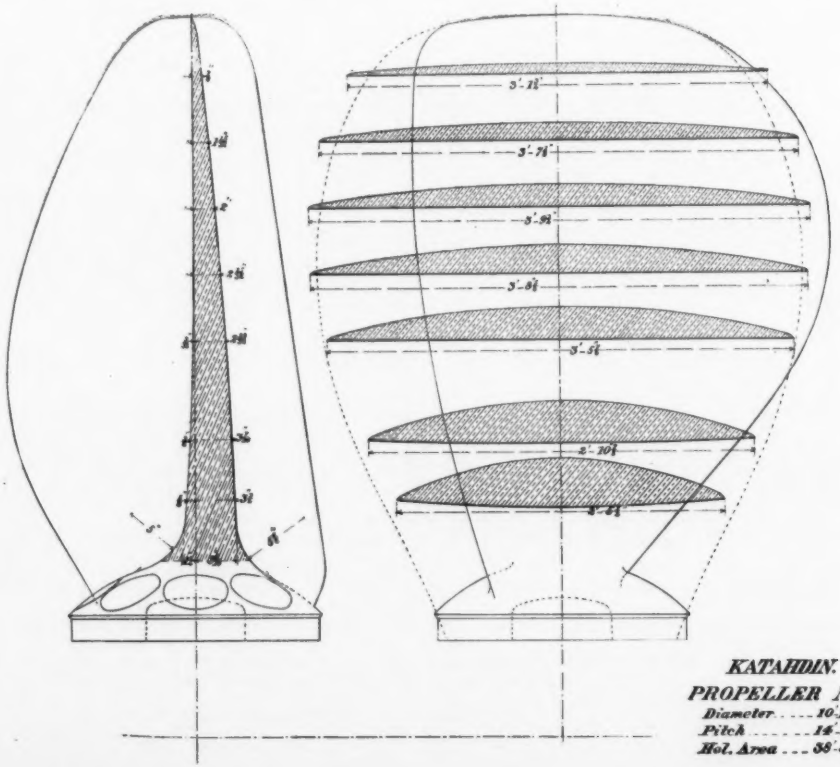
U. S. S. "KATAHDIN ON TRIAL."

	Starboard.		*Port.*
Steam at boilers, (gauge)		166.8	
Steam at engines, (gauge)	167.3		166.3
Steam at first receiver (absolute)	93.92		103.79
Steam at second receiver (absolute)	29.49		...
Vacuum in condenser, inches	24 03		23.86
Opening of throttle, in holes	3.57		3.64
Steam cut-off, H.P.	Link full out.		
I.P. } L.P. }	Linked up as much as possible.		
Revolutions of air and circulating pumps	57.75		71.5
Temperatures in degrees Fahrenheit, engine rooms		111.7	
fire rooms		112.7	
injection		57.2	
discharge	101.1		79.2
feed water		128.3	
Revolutions of fire room blowers, mean		464.3	
Air pressure in fire rooms, average, inches		1.5	
H.P. cylinder, mean pressure, pounds per square inch	34.11		29.06
I.H.P.	439.93		365.75
I.P. cylinder, mean pressure, pounds per square inch	38.06		29.57
I.H.P.	1,042.03		779.32
L.P. cylinder, mean pressure, pounds per square inch	18.24		16.75
I.H.P.	1,209.28		1,074.07
Equivalent pressure on L.P. piston equal to aggregate M.E.P.	40.58		34.61
Collective I.H.P. of each main engine	2,691.24		2,219.14
both main engines		4,910.38	
I.H.P. of air and circulating pumps	46.464		49.31
both air and circulating pumps		95.774	
main feed pump (one)		8.464	
four blower engines for forced draft		32.16	
water-service pump (one)		2.0	
fire and bilge pump		5.0	
engine-room ventilating blowers (two)		6.0	
steering engine		2.0	
dynamo engines (two)		6.0	
Collective I.H.P. of both main engines, with main air and circulating and feed pumps		5,014.618	
Collective I.H.P. both main engines, with all auxiliaries (A)		5,067.778	
Kind and quality of coal		Pocahontas, selected.	
Pounds of coal per hour		13,304.	
Pounds of coal per hour per I.H.P., collective, of all machinery in operation		2.625	
Pounds of coal per hour per I.H.P., collective, of main engines, main air and circulating and feed pumps		2.653	

	Starboard.		*Port.*
Pounds of coal per hour per square foot of heating surface.		1.1	
Pounds of coal per hour per square foot of grate surface.		37.6	
Square feet of cooling surface per I.H.P. (A)		1.316	
Square feet of heating surface per I.H.P. (A)		2.397	
I.H.P. per square foot of grate		14 316	
Ratio of helicoidal area of both screws to immersed midship section		.1562	
Ratio of disc area of both screws to immersed midship section		.2386	
Indicated thrust, pounds (I.H.P. main engines)	42,945.3		36,406.6
Indicated thrust per square foot of helicoidal area of propeller, pounds	1,192.9		1,011.3
Indicated thrust per square inch of surface of thrust-bearing pounds	63.76		54.09
Weight of propelling machinery (water included), tons		489.2	
Weight of propelling machinery per I.H.P., pounds		216.23	
I.H.P. per ton of machinery		10.35	
Slip of propellers, per cent	21.		18.8

PROGRESSIVE TRIALS OF SCREWS.

The first propellers put on the vessel before her launch, which had a diameter of 10.5 feet and a pitch of 15.25 feet, were found altogether unsuitable on a preliminary run. These were accordingly removed and the propellers (No. 2), shown in the drawing, substituted. A series of progressive trials was then made with these, by and at the expense of the contractors, the results of which are given in the table. The speeds were obtained by runs over a measured statute mile at Southport, Maine. Another set of propellers (No. 3), shown in the drawing, was then similarly tried with the results as given. The propellers at present on the vessel, and used on the contract trial, are two inches less in diameter, and the blades are $\frac{3}{8}$ inch thicker than No. 3. All propellers were three bladed.



KATAHDIN.

PROPELLER No. 2.

Diameter . . . . . 10'.10½
Pitch . . . . . 14'-4"
Hol. Area . . . 38'.56"

PROGRESSIVE TRIALS OF *KATAHDIN* WITH PROPELLERS No. 2.

Diameter, 10 feet 10½ inches; pitch, 14 feet 4 inches; helicoidal area, 38.56 square feet.

Date of trial.	Mean draught.	Displacem't on trial, tons.	Time over measured mile	Speed.		I.H.P.			Revolutions per min.			Slip of propellers, per cent.	Steam pressure, lbs. pr. sq. inch.	Perfor'nce constants.		Tide with or against.
				Miles per hour.	Knots.	S. engine.	P. engine.	Total.	S. engine.	P. engine.	Mean.			$\frac{D^{\frac{2}{3}} \times S^3}{I.H.P.}$	$\frac{M.S. \times S^3}{I.H.P.}$	
			m. sec.													
May 31,'95	14 feet 11¾ in.	2,158	6-1	9 97	8 66	173.1	213.9	387	70	72	71	13.75	148	280 2	788.7	A
"	"	"	5-0⅘	11.98	10.4	261	348	609	81	80	80.5	8 64	145	308.1	868.1	W.
"	"	"	4-49⅗	12 44	10.81	445	429	874	92	90	91	16.	135	242.	679.3	A.
"	"	"	4-8	14 52	12.61	613	716	1.329	105.5	102	103.75	14.02	127	252.	709.	W.
"	"	"	4-0	15 0	13.03	855	875	1,730	116.5	110	113.25	18 6	125	213.5	601.	A.
Aug. 17,'95	14 feet 10⅞ in.	2,139	4-7⅕	14.56	12.64	550	910	1,460	102	108.5	105.25	14.84	141	229 6	659.7	W.
"	"	"	4-0⅘	14.96	13 01	838	1,022	1,860	112.3	113	112 6	18.17	145	196 5	564.7	A.
"	"	"	3-40⅖	16.33	14 19	983	1,347	2,330	120.6	123 3	122	17 58	147	203.6	585.	W.
"	"	"	3-33⅕	16 89	14.66	1.388	1,721	3.109	130	131.6	130.8	20 58	159	168.2	483 3	A.
"	"	"	3-19⅘	18 06	15 69	2,181	1,890	4.071	146	139.3	142.6	22.03	135	157.5	452.5	W.
"	"	"	3-19	18.09	15 71	2.324	2,429	4.753	149.3	146	147 6	24.58	145	135.4	389.1	A.
"	"	"	3-16⅘	18.32	15.92	2.528	2,145	4,673	153	146	149.5	24.54	153*	143.3	411.8	W.
"	"	"	3-17⅘	18.23	15.84	2,745	2,315	5,059	154	147 5	150.75	25.55	155*	130.4	374.7	A.

* The performance would have been better if higher steam pressure could have been maintained during these runs.

The starboard engine is aft, and the port engine forward.

During the trials of May 31, all outside conditions were very favorable. Trial made 75 days after vessel came out of dock. Vessel trimmed aft 4⅘ inches.

During the trials of August 17, all outside conditions were very favorable. Trial made 153 days after vessel came out of dock. Vessel trimmed aft 3⅕ inches.

Natural draft was used up to 120 revolutions per minute; above that, an average air pressure of 1½ inches of water was used.

The highest number of revolutions at any time was 157 per minute, the corresponding I.H.P. being 5,749.

PROGRESSIVE TRIALS OF *KATAHDIN* WITH PROPELLERS No. 3.

Diameter, 12 feet; pitch, 14 feet; helicoidal area, 36.25 square feet; inclined element, 15 inches in 6 feet.

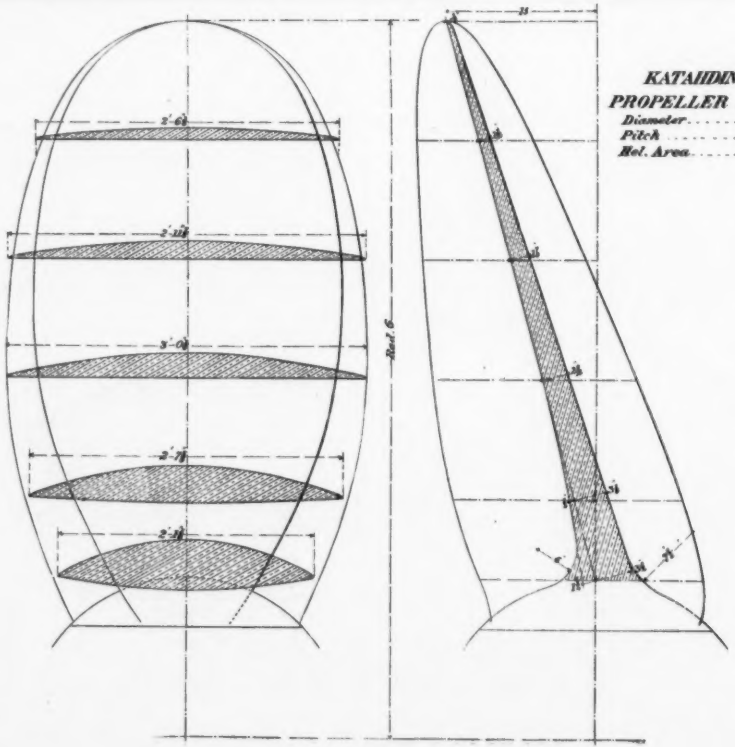
Date of trial, August 31, 1895. Mean draught, 14 feet 10¾ inches.

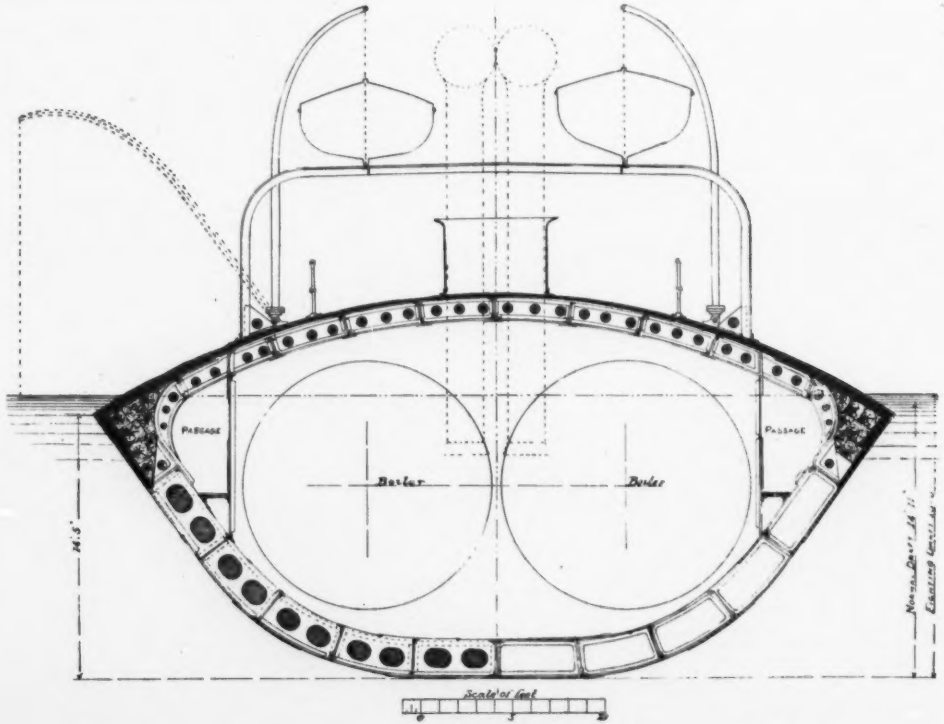
Displacement on trial, tons.	Time over measured mile.	Speed.		I.H.P.			Revolutions per minute.			Slip of propellers, per cent.	Steam pressure, lbs. pr. sq. in.	Perfor'ance constants.		Tide with or against.	Indicated thrust, in pounds.
		Miles per hour.	Knots.	S. engine.	P. engine.	Total.	S. engine.	P. engine.	Mean.			$\frac{D^{\frac{2}{3}} \times S^3}{I.H.P.}$	$\frac{M.S. \times S^2}{I.H.P.}$		
	m. sec.														
2,139	5–39⅘	10.6	9.2	284.2	163.6	447 8	72.66	69.66	71.16	6 43	108	288.8	827 7	W.	14,833
"	5–08⅘	11 67	10 13	347.3	332.5	679 8	79.66	82	80 83	9.29	130	253 9	727 8	A.	19.824
"	4–23⅘	13 67	11.87	642.	445 4	1,087.4	95	93 25	94 125	8 73	135	255.5	732 4	W.	27 221
"	4–12⅘	14 25	12.37	680.6	723 6	1,404.2	100	105	102.5	12 65	135	223.9	641.7	A.	32.287
"	3–49	15 72	13.65	934.6	894.2	1,828.8	109 66	111 5	110.58	10 66	130	230 9	661.9	W.	38,987
"	3–47	15 86	13 77	956.6	1,146	2.102.6	113.66	119.66	116 66	14 57	125	206.3	591.2	A.	42,104
"	3–32⅘	16.93	14 71	1.449.2	1,190.6	2,639 8	125	121.5	123 25	13.62	115	200 2	573.9	W.	50,489
"	3–28	17.31	15 03	1,743.8	1,696.4	3,440 2	126.66	132	129.33	15.89	105	163 9	469 8	A.	62.696
"	3–14⅘	18.48	16 05	2,407.6	2,272.2	4,679 8	136	140.5	138.25	15.97	142	146.7	420.5	W.	79.793
"	3–20⅘	17 98	15 62	2,303 2	2.253	4.556 2	134.5	140	137 25	17.63	147	138 9	398.2	A.	78.245
"	3–13	18.65	16 20	2.533.4	2,316.4	4,849 8	137.66	141 5	139.58	16.0	152	145.5	417 2	W.	81,903
"	3–16⅘	18 35	15 94	2,495.6	2,462.3	4,957.9	136 66	142.33	139.5	17.3	152	135.6	388.9	A.	83.775

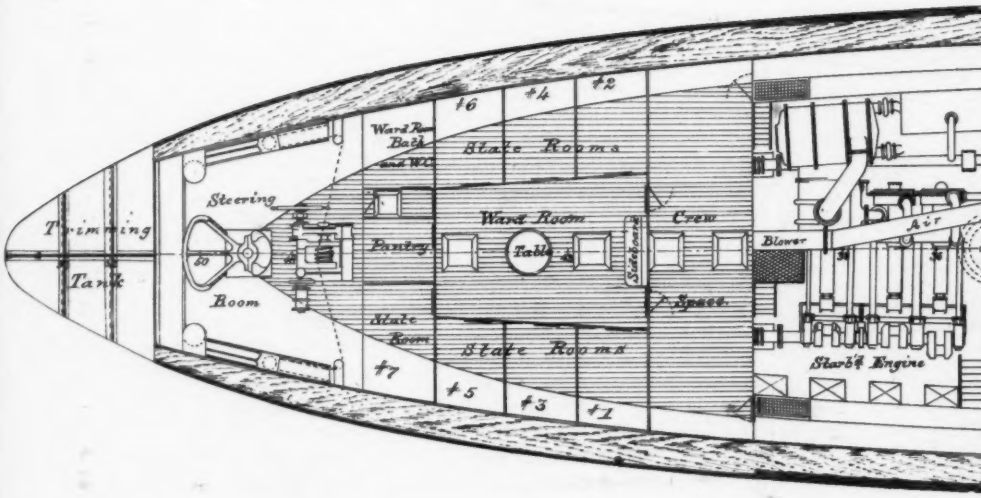
The weather conditions were very favorable, except strong wind towards end. Trial made 167 days after vessel came out of dock. Vacuum poor, never exceeding 24.5 inches of mercury.

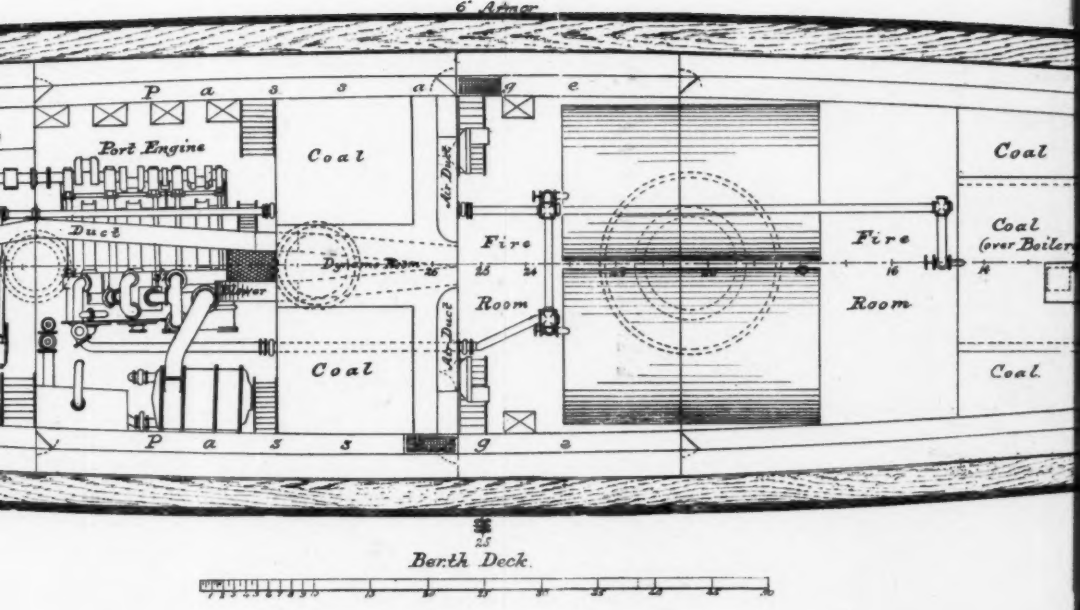
On the last four runs the steam pressure could not be maintained during the runs, dropping during each of the last two runs from 160 to 145 pounds while on the mile. This was due to inexperienced water tenders and firemen.

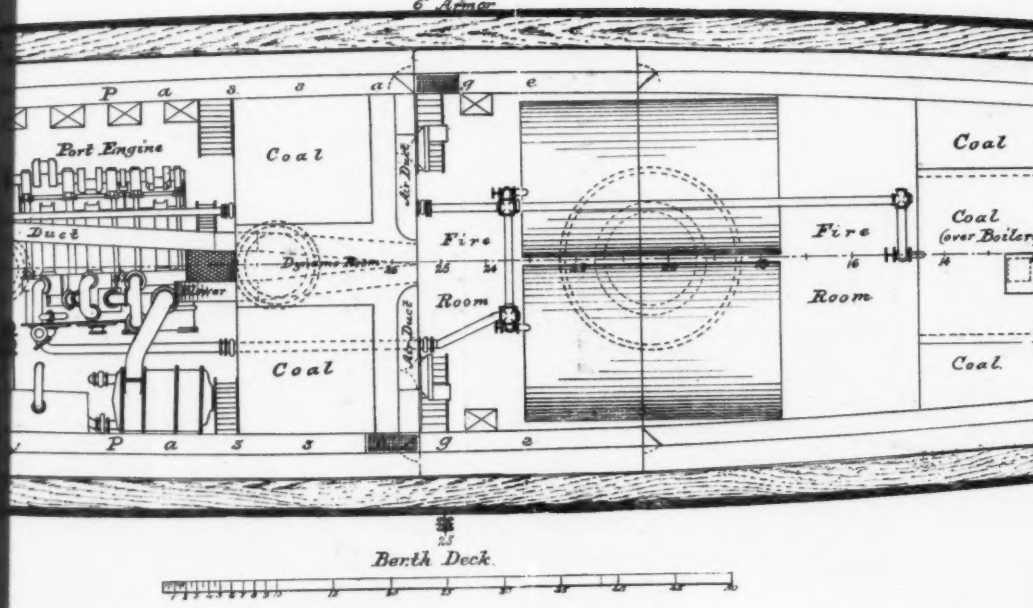
Natural draft was used below 130 revolutions per minute; above that, an average air pressure of 2½ inches of water was used.

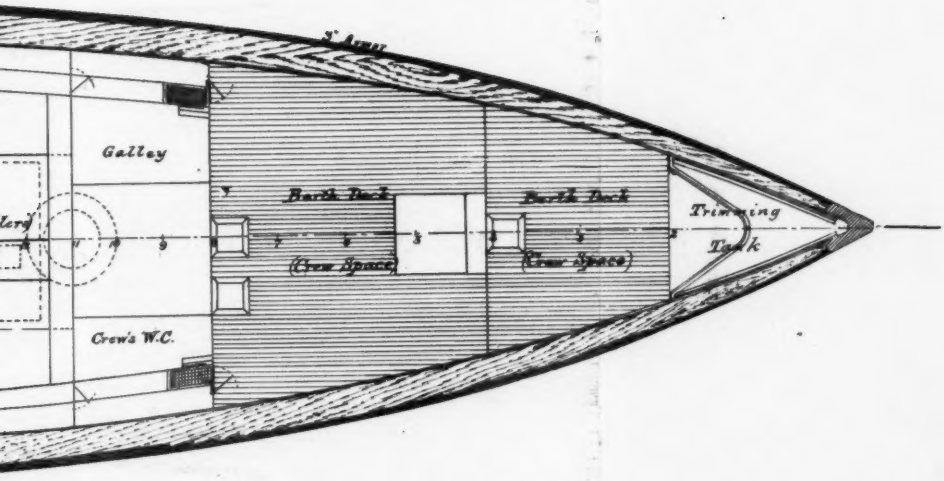

KATAHDN.
PROPELLER No. 3
Diameter ..... 12'.
Pitch ..... 14'.
Hel. Area ..... 36."


Passage
Passage
Boiler
Boiler
Scale of feet


Trimming Tank
Steering Gear Room
Ward Room Bath and WC
Pantry
State Room
State Rooms
Ward Room
Table
Sideboard
Crew Spaces
Blower
Air
Starb'd Engine
#6
#4
#2
#7
#5
#3
#1


6' Armor
P a s s a i
g e
Port Engine
Coal
Air Duct
Duct
Dynamo Room
Fire
Room
Fire
Room
Coal
Coal
(over Boiler)
Coal
Coal
Air Duct
P a s s g e
25
Berth Deck


6" Armor
Port Engine
Coal
Air Duct
Fire
Room
Coal
Coal
(over Boiler)
Coal.
Duct
Dynamo Room
Water
Berth Deck


Galley
Berth Deck
(Crew Space)
Berth Deck
(Crew Space)
Trimming
Tank
Crew's W.C.

RELATION OF THE DUTIES OF THE NAVAL ENGINEER OFFICERS TO THE PROBLEM.

By Passed Assistant Engineer John R. Edwards, U. S. Navy.

[Continuation of lectures delivered at the Naval War College, Newport, R. I., August, 1895.]

Second Lecture.

The following problem was proposed to the class at the War College:

May 10th.—War is imminent. The enemy is assembling in Halifax. He is expected to descend upon the New England coast. His probable plan is to occupy the coast and chief cities from Portland to Boston, thereby seconding certain movements of his land forces. His success depends upon his completing this occupation before June 10th, and maintaining it until July 10th. The force destined for this purpose is one or more fleets, whose total strength is three times that of our fleet, and 20,000 men in 50 transports.

Our available force is ordered to assemble for the present in Nantucket Sound.

May 20th.—War is declared. A fleet leaves Halifax, occupies Provincetown and blockades Boston May 23d. Is composed of 6 battleships, 8 armored cruisers, 18 cruisers, 12 gun boats, 12 torpedo boats. Gains and keeps touch with our fleet, wherever it may be, by means of scouts.

Our force is 5 battleships, 5 armored cruisers, 15 cruisers, 10 gun boats, 10 torpedo boats, 1 ram. A heavy monitor at Boston, a light one at Portsmouth and another at Portland, are to be retained at those points. We learn that a much larger force of the enemy is about to leave Halifax. It sails thence May 25th, blockades Portland, occupies Casco Bay, and gains touch with its Provincetown fleet, May 27th. Is composed of 10 battleships, 15 armored cruisers, 20 cruisers, 20 gunboats, 20 torpedo boats and 50 transports carrying 20,000 troops of all arms.

Design plan for meeting this demonstration.

Show best disposition of our forces and describe in detail our preparations for the campaign.

THE WORK OF THE CORPS OF NAVAL ENGINEERS BEFORE GOING INTO ACTION.

Early in April, the Secretary of the Navy and the Admiral commanding the defence fleet had several protracted consultations with the Engineer-in-Chief in regard to the threatening aspect of affairs on the New England coast. Imperative orders were given the Bureau of Steam Engineering to put the machinery

of every war vessel in the highest state of efficiency. Unlimited expenditures were authorized, and instructions given to effect such alterations as would make each vessel a most reliable fighting machine; but every improvement suggested in any vessel had first to receive the approval of the Admiral in command.

The Commander-in-Chief of the defence fleet, in urgent terms, requested the Engineer-in-Chief to nominate as Fleet Engineer an officer who possessed the following requirements: Ready in resource and of engineering constructive ability; not over 45 years of age, yet quick of judgment and with a broad knowledge of the plans of our various types of ships; capacity for work, and rare executive ability; with considerable sea service; great love and knowledge of his profession; of some personal magnetism, and of great will power and fixedness of purpose.

Nearly every Chief Engineer on the active list applied for this duty, but by reason of age their requests were denied.

It was urged by the Admiral, who was under 55 years, that no one of any staff corps who had served in the last war should, on account of the age of those officers, do active work at sea. Line officers might go as commanders of vessels, but then they should only be sent on battleships and armored cruisers, or as Flag Officers.

It was recalled to mind that Admiral Farragut's Fleet Engineer was only 33 years of age when the forts below New Orleans were passed. In looking across the sea it was observed that the English Admiralty appoint as Engineer-in-Chief of their great and powerful navy only a comparatively young man, who, of course, is continued in office if he shows matchless talents for the work. We have followed their example in this respect, and when able men have reached the position of Bureau Chief they are never disturbed. Even in time of profound peace and when such conservative action as the building of the *Charleston* with her compound engines had been authorized, our present great Engineer-in-Chief was appointed—a man who at that time was about 47 years old.

Some difficulty was found in securing an officer to fill the post of Fleet Engineer, which was regarded by the Secretary as

next in importance to that of the Fleet Captain. An examination of the January Register showed that every officer on the list of Chief Engineers was beyond the age limit set by the Admiral.

With great earnestness the Engineer-in-Chief urged that the Admiral's wishes be respected in regard to the request for a Fleet Engineer. The old officers insisted on being sent. A very able Fleet Engineer was ordered who was over 50 years of age. Within two weeks he physically collapsed under the great strain of almost continuous day and night work. During that period he had rendered invaluable service to the fleet, and some of the changes, made under his supervision, had an important effect upon the result of the great naval battle fought off the Massachusetts coast.

His successor was one of the young officers who had been trained under the personal supervision of the Engineer-in-Chief. With such a preceptor, it was but natural that he had acquired decision and quickness of judgment and a confidence which was ready to assume great responsibilities. Thoroughly conversant with the definite policy which had actuated the work of the Bureau of Steam Engineering, he knew the strength and weakness of our ships, so far as their structural arrangements and motive power were concerned. Incessant work for a dozen of years in studying marine engineering questions, both at the Bureau and at sea, made him no stranger to the duties before him. He had made one cruise at least, as a virtual Chief Engineer, although the official records showed that he served as assistant.

The Secretary of the Navy considered his duties of such importance that, in a personal interview, he impressed the fact upon this officer that the preliminary work of the Corps of Naval Engineers might avert the calamity, which a sorrowful nation was hoping and praying would not prove a verity.

The Secretary then commended him to the favor of the Admiral of the Fleet; and with the knowlege that, no matter how great the service he might render, there would be no grateful nation to hold him in remembrance, he entered upon his duties. He only knew that the Recording Angel wrote in letters of gems

those deeds of valor and worth which have passed unnoticed and unrecorded on earth.

Within a few days the Commander-in-Chief was impressed with the fact that in his Fleet Engineer he had a most valuable assistant. Casting aside the traditions of the past, he showed himself a great man by overcoming the prejudices of his four decades of naval life. Into his full confidence this fleet officer was taken, and then he was given carte blanche to prepare for the inevitable battle.

Here are some of the changes that were wrought:

One of the scouts was sent for several hundred bunker plates and frames of standard size, so that the upper bunkers of the several ships could not only be coaled more rapidly, but be made more habitable in action. Under the direction of the carpenter, the holes in the deck planking were cut to a size scant of that required.

Another scout was sent to the nearest seaport to Lynn, to bring men and electric drill outfits for cutting additional holes in the protective deck. Doors for closing the openings thus made were ordered from Bethlehem and Pittsburg, the detail drawings having been made by one of the assistant engineers.

Emergency chutes which opened directly into the several fire rooms were built within the bunkers. These extended from above the upper bunkers, through the protective deck, and had suitable doors for preserving the water tight features of the vessel. The extra coal carried on deck could be delivered into the fire room without opening a bunker door; and with the increased number of deck scuttles fitted into the upper bunkers, all the deck force not otherwise engaged could, in a chase or when escaping from an enemy, carry coal from this bunker and empty it into the emergency chutes. This would not interfere in any way with the coal passers working below.

And, if one of the longitudinal bunkers should become filled with water, coal could be brought to the fire room through these chutes and supplied to the furnaces. As formerly arranged, it was absolutely necessary to open a bunker door to procure coal, and in the event of a hole being made in the hull, either

by a torpedo or the vessel striking some object, the doors leading to the impaired bunkers had to be closed. The Fleet Engineer regarded these emergency chutes as of vital importance.

He called the attention of the Admiral to the ill-contrived arrangement of deck pumps as fitted on nearly all the ships.

On the deck of a certain vessel in the fleet, the three athwartship passages were blocked by six Downton or Stone Pumps. The brakes, when manned, required more deck room than an eight-inch modern rifle. When called to fire quarters, and with 96 men on the cranks of the six hand pumps, working against a 25-horse-power steam pump, a complete stoppage of the deck outfit occurred.

The Admiral, alarmed at this state of affairs, called a survey upon the fire main and deck pumping arrangement. As bilge pumps, they were found to work so slowly that they were practically useless. No one could give any satisfactory reasons for their being placed in a modern vessel. At sea, where steam was always maintained, they were never used. At a navy yard, the ships would be laid up within a short distance of a fire plug, and for the lone watchman in charge of the ship, the use of a water bucket would be the best method of fighting a fire single-handed.

To the great joy of all the gun crews, the deck pumps were disconnected and all sent to a navy yard, where they took up valuable room in one of the buildings, thus robbing the scrap pile of its legitimate prey.

The valuable space secured on board by the removal of these pumps was utilized in many ways. Later, the capture of one of the enemy's cruisers was due to the fact that one of our vessels was able to prolong the chase for several hours, by reason of carrying 30 additional tons of coal in jute bags in the space previously occupied by the deck pumps.

Formerly, when all the boilers were in one compartment, and this became flooded, the deck pumps might have been of service. But in a modern ship, where the boilers are in several compartments, it is not likely that all the fires will be put out at once. If such a calamity should occur, the quicker the crew took to

the boats the better. Those who remained with the pumps would probably find a watery grave.

As an alternative, in case the space gained by sending ashore the numerous deck pumps was not wanted for coal, it was suggested that a coil boiler plant and steam wrecking pump, which would be of some practical service, be installed. Steam would always be kept low on this boiler when the ship was under way.

INCREASED HEIGHT OF SMOKE PIPES.

Additions were made to the height of all the smoke pipes. This excited some comment, as it was supposed that we already had tall funnels on our vessels. An examination of the *Marblehead*, a vessel which was said to have been ruined in appearance by her tall pipes, showed that their tops were only fifty-seven and one-half ($57\frac{1}{2}$) feet above the grates. Those who had made a cruise in the *Chicago*, previous to 1895, hardly recognized the ship with her new and tall pipes. In the eyes of the Admiral she was beautiful, for he knew that these high shafts were marks of efficiency, and that they increased her sea speed. The cruising speed of the fleet was materially assisted by this action and the efficiency improved.

A RADICAL CHANGE WAS MADE IN THE FIRE MAIN SYSTEM.

Instead of a line of piping, which contained so many angles and sharp bends that there was practically a stop to some of the plugs, a carefully devised arrangement was secured. Fire plugs were placed everywhere, and only full opening valves fitted. The lengths of rubber hose were such that one man, or two at the most, could run out a section. At least two steam pumps, one forward and the other aft, were installed outside of the engine and boiler compartments. These pumps had coal and side armor protection, and, being fitted with relief overflow valves in the pipes, were meant to be run continuously during action.

As an example of a poorly designed lead of piping, one of the vessels may be cited, where the fire bell was rung during the Admiral's inspection. The engineer's force led out their two sections of hose; two powerful steam pumps, in perfect order

were at work on the fire main; two gun's crews helped to hold the hose to prevent kinks, and yet only a small stream issued from the nozzle.

The complaint has come from almost every one of our men-of-war that the Officer of the Deck, while constantly asking for more water on the morning watch to wash down decks, could not secure it, although powerful steam pumps below were working at their utmost power. If sufficient water can not be secured to wash the deck, what are we to do in case of fire?

INSTALLATION OF ADDITIONAL FANS AND BLOWERS.

The Fleet Engineer gave warning in regard to the enormous quantity of top hamper with which only too many of our battleships are oppressed. An "Engineer" editorial of June 5th says: "We have deck houses and bridges and boats and cowls. These would be converted in five minutes by machine and quick firing guns into matchwood. Probably this matchwood would be set on fire. No wooden structure of any kind should be permitted on the upper deck. This was the lesson of the *Yalu*. As to the funnel, it is clear that with anything like a smooth sea and a moderate range, machine guns could cut these off pretty short. The cowls and ventilators would be reduced to small scrap.

"The existence of a war ship as an antagonist must depend in action on her fans, and we have never yet been on board a man-of-war, in which the fan arrangements appeared to be the best possible."

The blower arrangements were improved, but not to the extent that could have been done if more time had been given. Temporary provision was therfore made for the ventilation of the vessels, in case the ventilators were cut away by small shell. The vital air shafts were so arranged that nothing the enemy could do would affect them. It was strange that the ventilating question had to be settled on the eve of battle.

QUALITY OF THE FUEL.

An inspection by the Fleet Engineer of the bunkers of the several ships showed that they contained various kinds and

qualities of coal. There were anthracites containing from 2 to 14 per cent. of ash and there were even mixtures of the red and white ash varieties. There were bituminous invoices which had been exposed to the weather and whose hydro-carbons had, in great part, volatilized and passed off. There was even a quantity of fuel which resembled peat more than it did coal. The sizes varied from steamboat to barley buckwheat. He knew that the efficiency of the vessels would be impaired by the possession of such fuel, for in action, when it would be necessary to force the fires to their utmost, there would be no time to select coal. That within reach would be taken, and such a mixture of various inferior kinds, as was found by the Fleet Engineer in the ships, would result in the rapid formation of clinker, which, containing a large percentage of unconsumed carbon, would not only entail a great waste of coal, but decrease the efficiency of the boilers. This investigation resulted in the appointment of a Board of Naval Engineers, to determine the quality and character of the coal supplied to our war vessels on the Atlantic coast.

VIEWS IN REGARD TQ SUPERIOR BOILER POWER.

Repeatedly during their many consultations, the Engineer-in-Chief had impressed the Admiral with the superiority of our vessels in "boiler power" over that of the enemy.

It was shown that in battle our vessels would be kept moving, and that the enemy would be given no chance of preparing for a rush at full speed under forced draft; that our ships, with larger boiler power and their increased ratio of grate surface, would be in an efficient state when those of the enemy would have their fires full of clinker, tubes choked and firemen exhausted.

In a series of letters to "Engineering," a correspondent, "Argus," calls the attention of the Admiralty to the superiority of the United States in this respect. He says: "The question is, *Are British ships supplied with such boiler installation* as compared with those in ships of the same class belonging to possible enemies, as to secure us the advantage, both in tactics and strategy in the event of war? And the answer is: *They are not, most emphatically not, neither existing ships, nor ships building.*"

The Admiral informed himself of the *sustained speed* and boiler power of the vessels, class for class, so that he might know just what tactics to pursue. And in doing this, he was not led astray by the delusive figures given in the reports of trial trips made on "normal" displacement, when perhaps there was not as much as one-half the coal and stores on board that the ship would carry when ready for an engagement; but he compared them on the basis of their load displacements and their boiler powers. For, given equally good men in each ship, and an equally good quality of coal, of two ships having the same displacement, that one will be the faster which has the greater boiler power.

Taking them class for class, our ships are more powerful in their machinery than those that will operate from Halifax. The accompanying table shows that the *Indiana* and *Massachusetts* are but slightly inferior, actually, to the battleships of the British *Royal Sovereign* class; but as our vessels are of considerable less displacement, it will take about 20 per cent. more power to give the first class battleships of the enemy the same speed as the *Indiana* class. This they have not; and so it may be confidently accepted that, so far as sustained speed is concerned, our ships are at least equal to the best that the enemy can concentrate. When it comes to the *Iowa*, we have a ship that in boiler power is far superior to anything that can be brought against her in the battleship line, and is only inferior in boiler power to armored cruisers of the enemy.

Coming to the armored cruisers, the *Maine*, though larger than the vessels of the *Australia* class, is shorter and has not such good lines for speed; but she has greater boiler power, and may be expected to maintain nearly, if not quite as good speed as the *Australia* class. The *New York* is fully 15 per cent. more powerful than the *Blake*, and the *Brooklyn* has practically the same power as the *Blenheim*, so that the ships we have of this class are not at all inferior.

Coming down to the protected cruisers, it will be seen that the *Columbia* and *Minneapolis* have fully 75 per cent. more boiler power than the first class cruisers of the *Edgar* class; and while they will be of greater displacement when fully loaded, they are,

in point of speed and endurance, unapproachable by any vessels of the enemy's fleet. The *Olympia*, though much smaller than any of the hostile first class cruisers, has greater boiler power than any of them, and is, therefore, capable of doing any duty in scouting or raiding that could be expected of a ship in possession of the enemy; and, owing to the superior design of her boilers, she could do this duty much more economically.

COMPARISON OF THE BOILER POWER OF VESSELS OF THE U. S. AND BRITISH NAVIES.

Ship.	Displacement.	I.H.P.	Grate Surface.	Heating Surface.	Ratio of Heating to Grate Surface.
Royal Sovereign Class	14,900	11,500	731	20,348	27.8
Indiana	11,600	9,000	616	19,195	31.1
Iowa	12,000	11,000	756	24,038	31.8
Australia Class	5,600	8,835	514	15,502	30.1
Maine	6,800	9,292	574	19,015	33.1
Blake	9,000	14 525	871	27,192	31.2
New York	9,000	17,400	1,052	32,958	31.3
Blenheim	9,000	21,411	1,135	31,073	27.4
Brooklyn	9,000	17,000	1,016	33,429	32.9
Edgar Class	7,700	10,517 12,851	812	24,908	30.7
Columbia	8,100	18,500	1,408	45,221	32.1
Minneapolis	8,100	20,860	1,520	50,147	33.0
Vulcan	7,000	12,062	564	15,861	28.1
Texas	6,800	8,600	532	19,912	31.8
Mersey Class	4,050	6,151	388	11,565	29 8
Charleston	4,050	6,666	436	15 577	35.7
Forte Class	4,360	9,274	575	15,641	27.2
San Francisco	4,300	9,913	577	20,135	34.9
Archer Class	1,770	3,754	222	6,836	30.8
Yorktown Class	1 800	3,400	220	8,092	36.8
Medea Class	2,900	9,268	526	13,264	25.2
Cincinnati Class	3,213	10,000	617	20,179	32.7
Apollo Class	3,550	9,274	575	15,641	27.2
Pallas Class	2,600	7,469	410	11,025	26.9
Detroit Class	2,100	5,400	394	11,004	27.9
Buzzard Class	1,140	2,000	...	...	...
Machias	1,200	1,800	120	4,590	38.2
Royal Arthur	7,700	10,086	731	24,828	33.9
Olympia	5,800	17,000	828	28,300	34.3

When we examine the boiler power of the smaller cruisers, we find that we are quite as well off as we are in the larger ones. The *San Francisco* and *Baltimore* class of cruisers are superior to those

of the *Forte* class, while the *Cincinnati* and *Raleigh* are ahead of the *Apollo* and *Medea* classes. The opposing fleet also has smaller cruisers somewhat like the *Detroit* class, the *Pallas*, *Pearl*, etc. Although they are rated at 7,500 I.H.P. against 5,400 for the *Detroit* class, an examination of the table will show that there is practically no difference in the boiler power, and that, therefore, we should expect almost as much power from the *Detroit* as from the *Pallas;* but the latter vessel is some 500 tons larger than the *Detroit*, and, therefore, the *Detroit* ought to be the faster.

The vessels of the *Mersey* class, of which there are only four in the British Navy, are comparable with the *Charleston*, which has a good margin of power in excess of the *Mersey*, and, although slightly larger, is unquestionably faster.

Another point that must not be overlooked, in connection with the boiler power of the ships of our fleet, is that there is a larger ratio of grate to heating surface in all of them, and that they will consequently be able to do their special duty with a less expenditure of fuel.

It will be particularly noticed that, in the three types of vessels in which the plans were purchased abroad, we have not that marked superiority over our trans-Atlantic cousins in horse-power.

FLOODING COMPARTMENTS.

An inspection of the fleet showed that in some of the vessels no provision had been made for flooding every compartment. Fire is an element which will have to be fought by the crews of a war vessel, and the occasion may arise when a compartment will have to be flooded to save a ship. This was one of the lessons taught at the Yalu.

An exceedingly able writer in one of the June numbers of "Harper's Weekly" speaks as follows upon this subject:

"When the fires began to burn fiercely on some of the Chinese vessels, it was found that there was no means of flooding the compartment where the torpedo heads were stored, preliminary to being brought into action. This was an added source of danger, and it became necessary to throw the torpedoes over-

board at once. It is probable, as a result of this, that further improvements will be necessary in the construction of war ships to avoid such danger in action."

Without going into dock, flood cocks were attached to the hull, and pipes fitted, and the defect of not being able to fill the compartments with water was overcome.

Everything was subordinated to placing the boilers and engines in a state of maximum efficiency, for the Engineer-in-Chief had convinced the Secretary of the Navy that in a modern war vessel the motive power had become a weapon, and that for special purposes it was superior to the gun.

Speed, and particularly its control, is the cardinal element of tactics. Ability to manœuver is now more dependent upon the number, form and position of the propellers, and the shape of the hull, than it is upon the skill of the commander. They are, therefore, the qualities and attributes of a weapon.

But the motive power is more. It is a defense, and in many respects of more importance than the armor. It gives the commander the option of avoiding or forcing a contest and, with marked superiority in speed, he may determine the strategy of the battle.

There are other ways of rendering a ship useless than by killing the men at the guns. Continuous work in an ill-ventilated and contracted fire-room will cripple the efficiency of the steam weapon below the protective deck.

That voyage of the *Columbia* across the Western Ocean is going to be fraught with great results. What mysterious power suddenly gave our people confidence when they read of the splendid run of the matchless *Pirate?* It was because the Nation had a glimpse of the future, and was told that speed was *par excellence* the weapon of the ship of war.

The run of the *Columbia* between the Needles and Sandy Hook settled the speed question of our war ships for the remainder of this century. Those who think our ships go too fast are likely to find out that our people believe such critics move too slowly. And those who complain of the excessive horse-power of our vessels will find few people to argue with them.

FLOATING WORKSHOPS AND REPAIR SHIPS.

There had been fitted out for the use of the defense fleet two floating workshops or repair ships. They were called the *Corliss* and *Fulton.*

The men in charge of the several tools had been so instructed and drilled that, in case of the capture of the repair ship, some vital part of each machine could be disconnected very readily. The ships were in great part fitted with duplicate machine tools in order that the continuance of any special work could not be interfered with. And, in case it was found necessary to sink one of the vessels to prevent her from falling into the possession of the enemy, the other would still be available to carry on the special work.

It is unnecessary to give a list of the machine tools and outfit, but in general it can be said that they were the equal of anything of that description afloat.

The workmen were nearly all members of the New England Naval Reserve, and probably had no superiors in the world as rapid and skilful artisans. Trained in the use of small arms and rapid fire guns, and subservient to discipline, their work and conduct received the special commendation of the Commander-in-Chief.

All repairs were made under the direction of an Engineer Officer, who had as his assistants some of the ablest mechanical engineers in New England. These men had voluntarily offered their services until the close of the war, and their patriotic employers had sent to the repair ships the pride and pick of their several establishmments.

The equipment of the repair ships was placed absolutely in the hands of the Engineer-in-Chief. In general it may be said that the outfit was of such a character that it was capable of fitting up any casting from a two-ton cupola. Any plate whose width was less than 48 inches could be handled successfully, irrespective of length. Particular care was taken that the repair ships were not loaded down with too many tools. They were not intended, nor was it possible, to make them floating dock yards. The impracticable suggestion, to equip them in a manner

resembling a ship construction plant, was not seriously considered. Plates, which could not be conveniently handled aboard such a ship, were too large to be manipulated anywhere except at a great ship building plant.

It would take many lectures to tell of the work accomplished on these vessels, but the Proceedings of the American Society of Mechanical Engineers for 189–, tell in detail of the work accomplished and the scope of their usefulness.

AUXILIARY NAVAL REPAIR STATIONS.

As the usefulness of a repair ship is greatest for service abroad, or when the fleet is operating at some distance from its base, the Navy Department, after mature deliberation, decided upon another method of making the ships efficient.

The Secretary, therefore, ordered the Engineer-in-Chief to co-operate with the Admiral in command and to make the necessary arrangements to establish repair stations.

The American Society of Mechanical Engineers and the Marine Engineers' Beneficial Association of the United States, through their executive officers, called upon the President and tendered their services, requesting particularly to work under the special direction of the Engineer-in-Chief.

It was realized by the President that our only hope of success, (with our naval force one-third as powerful as that of the enemy,) was in having our fleet maintained in the highest state of efficiency, so that our maximum force could be utilized for a decisive blow at almost any hour.

The president of the Marine Engineers' Association had special interviews with the Secretary in regard to the status of their members upon entering the naval service, but more will be said on this subject in another lecture.

Six of the best appointed engine plants in Rhode Island, Connecticut and Massachusetts, which are accessible to the sea, were turned into Auxiliary Naval Repair Stations. There the great bulk of the repairs of the fleets was made.

Blue prints of the machinery drawings of all the vessels of our fleet were sent to each of these establishments. Many of the

most skilled mechanics of the various shops were taken aboard the ships and given instruction in regard to the absolute necessity of implicitly following orders, both in regard to the character of the material and the details of the various parts.

Under the direction of Naval Chief Engineers were eminent Mechanical Engineers, who were placed in immediate charge of these repairs. Thoroughly posted in regard to the resources of the plants, and with an intimate knowledge of the personnel of the various establishments, repairs were made with surprising rapidity. The fast steam yachts *Vamoose* and *Feiseen*, and other boats of their speed, were detailed as despatch boats between the fleet and the harbors nearest to the repair plants.

Whenever the repair was of a small but important nature, but beyond the resources of the fighting ships, orders were given in the different shops to make several of the parts required. The new pieces were sent aboard by different despatch boats, and it was quite certain that at least one part would reach the vessel it was intended for.

COMMUNICATION BETWEEN CONNING TOWER AND ENGINE ROOM.

A very decided improvement was made in the method of communicating between the conning tower and the engine room. Changes were made in the size, shape and location of the mouth pieces of the speaking tubes. Additional mechanical telegraphs were installed, likewise a simple, reliable bell pull. Those contrivances of the dreamer, which may be a success of the morrow, but which are unreliable toys of today, were discarded. Suitable key words for certain work were agreed upon. When it was found necessary to pass orders by word of mouth, single expressive terms which could not be misunderstood were employed.

Our enemy had also swept from their decks the worthless contrivances for communicating with the engine room, for a London "Engineering" leader had warned them as follows:

"For example, what is the use of an elaborate series of speaking tubes from the forward conning tower to the engine room, down which no intelligible message can be transmitted, even

under ordinary conditions when the engines are running, and which would be utterly useless in the noise of an action. What can be said in favor of electrical signalling arrangements which cannot be trusted even on a peaceful cruise. The engineer would take very good care to provide signalling arrangements which, if they did not permit the captain and the chief engineer to consult with each other, would not fail to tell the latter what the former wanted the engines to do."

ENGINE AND FIRE ROOM WATCHES.

The fire and engine room watches of all the vessels were drilled and trained, so that each one of the enlisted men could do the duties of the next higher rating. As a victory was looked for, the Fleet Engineer thus provided in part for future contingencies. He thoroughly realized the fact that the engineer's force would be well employed and under great pressure before, during and after the battle. The collapse of many good men could therefore be expected, and provision had to be made for such casualties.

He knew also that, in the case of victory, it would be reasonable to anticipate that some of the enemy's ships would be captured. Such ships would either have to be destroyed, or prize crews placed on board to take them to an American port. Such crews must necessarily contain a large proportion of officers and men of the steam department, which could not be arranged, under existing circumstances, without crippling the fighting power of our own vessels.

The Fleet and the several Chief Engineers had given serious consideration to the best method of arranging the fire and engine room watches. The Admiral and his council of commanders, after mature deliberation, had decided that the organization of the engine force could best be done by the chiefs of the respective ships.

In general it was determined to arrange the watches as follows:

1st. When chasing, or escaping from an enemy, or when making maximum speed for a protracted period. The men should be placed in two watches so long as this did not continue beyond

thirty-six hours. This was terrible work when taking into consideration the circumstances under which the men lived. After battling with fires forced to their utmost, it was impossible for men to sleep and rest until they were freed of the strain and excitement. In order to have the men secure some rest between the watches, it would be necessary to work them six hours at a time.

For a long voyage, the men should be placed in three watches, and then relieved of all drill and routine duties. And in addition, there would be a detail of men from deck helping to get out coal. It must be realized that no one can take the place of the fireman, no matter how cheerfully he may volunteer for the duty. It is a mistake to suppose that the duty of a fireman is similar to that of a navvy; the navvy simply requires strength, the fireman requires also skill, brains and courage. All that the deck force can do to assist those below will be to help bring the coal to the fire rooms.

The Chief Engineers of all our vessels have been urging that the coal passers be taken out of the Powder Division.

In an official report, the Chief Engineer of the *Columbia* wrote: "The force of firemen and coal passers is not sufficient for natural draft, steaming with all boilers, except when coal is very convenient to the fire room."

This is what the Chief Engineer of the *Chicago* wrote upon the same subject: "I deem it my duty to state that the personnel is entirely too small to admit of the proper care of the machinery, and utterly inadequate to sustain the proper efficiency of the Engineer Department during an engagement. One-third of the Department being transferred to the Powder Division, leaves many important stations, such as stop valves, bearings, &c., without special attendance, which will lead to serious disaster during battle." Captain Mahan comments thus on this report: "The above representation of the Chief Engineer shows, in my opinion, the necessity of a general consideration of the question of actual necessities of an engine room in action. The efficient working of the Powder Division of the *Chicago* required that deduction from the Engineer Force."

Is it not possible to help matters, both in the engine room and on deck, by improving the arrangement of magazines, and the manner of supplying and hoisting the ammunition? Surely some better way can be found than the present methods.

The great weakness of the *Columbia* and *Minneapolis*, besides the arrangement of their coal bunkers, lies in the method of supplying ammunition, and if this defect were overcome, the Powder Division could do more efficient work with fewer coal passers. More men could then be secured for the fire room, where there would be urgent duties for them to perform.

Another engineer officer writes: "It takes one-third of our force to run launches, keep steam on the ship, evaporate and distil water, run pumps and attend to the numerous auxiliaries. When a third is taken away every day to assist the Powder Division, it leaves us the remaining third, an insufficient number, to do the work of the Department."

Our highest officers pay tribute to the efficiency of the drill of the Naval Reserves; and if this skill can be acquired by working one hour a week for ten months of the year, why can't our engineer's force secure all the experience they require in this direction by drills, two days of the week the entire year?

The entire engineer's force should be instructed in everything relating to a gun, but they would take much more interest in these drills if one of the junior engineer officers could have charge of them. With their Annapolis training, surely these officers are competent to do this work. And it is not at all improbable that, if a shower of bullets should clear the decks of our gun division officers, an occasion might arise where the services of the junior engineers would be required to take charge of the batteries.

STATION BILL WHEN IN ACTION.

It is not probable that a naval conflict in the future will be prolonged beyond six hours. For that period, and for an hour or two before and after the battle, the entire engineer's force will have to work continuously. Improvements can and should be made in the manner of supplying ammunition. If this were done, the Powder Division, with one-sixth of the engineer's

force, could do better work than they now accomplish. Two-thirds of the force should be stationed in the engine and boiler compartments. With one-sixth on deck helping to supply shell to the guns, there would then be a remaining sixth to form an "Emergency Watch," which would be under the charge of an assistant engineer. This squad would look out for the fire hose; stop valve gear on deck; make repeated examinations of the bunker water tight doors; observe the operation of every steam and hydraulic machine outside the engine and boiler rooms; inspect at intervals the leads of the steering gear; stand by to work the steering appliance from below if the deck gear should be carried away; and be in readiness to effect temporary repairs or overhaulings to any inefficient or disabled auxiliary. As they would be picked men, they might be able to render effective aid should any of the gun mechanism jam. It is almost impossible to tell of the many possible ways in which their services could be utilized.

Mechanics are not to be found aboard ship in the deck force. I have never seen a good vise hand outside of the engineer department aboard any of the fifteen ships that I have been attached to. There have been excellent blacksmiths, but they were neither capable nor anxious to do the work of either boiler maker or machinist. I am quite positive that during the three years I was aboard the *Petrel*, we never had target practice without having some slight hitch in the breech mechanism of one of the six-inch rifles. This was not the fault of the guns, but it was due to stupid work on the part of some Wallabout recruit or Asiatic "beach comber." Therefore the usefulness of the "Emergency Watch" is vast in its possibilities, and if these men could have special drills in dismounting guns, &c., they might become an important factor in helping to determine the result of a battle.

Wherever it was possible to do so, improved methods of heating the feed water were substituted for those now in use. In several of the ships part of the bunkers were torn out to find room for these appliances. The Superintending Marine Engineers of several great English steamship companies have told me that, in their opinion, the one great cause of the breakdown of

the Scotch boiler in the British Navy has been due to the fact, that the engineers were not given sufficient space to install a suitable heating plant for the feed water. On some of their ships, the boiler power has been imperrilled by fitting some worthless heating tank, instead of a properly designed feed water heater. Their engineers know very well that the water has not been going into the tanks hot enough, but they are powerless to remedy the evil, as a request for room for this purpose is denied, with the answer that the engineer has too much room already.

In the short space of time that was permitted to prepare for battle, the development of electric power for many purposes suggested in the engineer's department could only in part be carried out. No better authorities on the question can be found than S. Dana Greene and W. S. Shallenberger, both formerly of the Naval Service, and the absence of some of the motors recommended by them was greatly regretted on all the ships, on the day when they went into action and met the enemy.

Third Lecture.

THE WORK OF THE CORPS OF NAVAL ENGINEERS IN BATTLE.

On the night of May 29th, the steam yacht *Now Then*, one of the Mosquito fleet, steamed into the harbor of Vineyard Sound. She reported that one of the enemy's battle ships and one of the heavy cruisers had been seen moving slowly to the eastward, accompanied by a torpedo boat, a steam collier, and one of the floating workshops. The two large vessels appeared to be in distress, for the torpedo boat moved constantly from the workshop to the war vessels. The *Now Then* had watched these vessels until dusk. She had to keep too far away from them to gather any definite information, but the Ensign in command felt convinced that the enemy's vessels were bound either for Halifax, or some point to the eastward, where important repairs were contemplated.

This news was communicated to the Commander-in-Chief, who immediately congratulated the little scout on her pluck and good luck. The Chief-of-Staff was ordered to have the

fleet leave harbor before midnight. The Admiral's face brightened as the Captain of the Flag Ship pleasantly remarked, that the little scout had a very suggestive name for a time of battle.

CONDITION OF OUR FLEET.

Our ships were in a high state of efficiency. They not only had clean hulls, but full crews. The bunkers nearest the fire rooms were filled with selected coal, and to save the men from overwork, this coal had been placed aboard and stowed by shore people.

The several departments of every ship had a full supply of stores, sufficient not only for ordinary cruising, but for unusual emergencies. The crews were in excellent health, having had considerable rest, although standing watch and watch everywhere, except in the engine and fire rooms. Under the peaceful shelter of the harbor highlands there had been no fear at night of torpedo attack. The men were therefore free of that intense strain under which the sailors of the blockading fleet were supposed to labor.

There were no sick aboard, and as an almost perfect commissary system had been established, the crews were prepared for protracted and severe work.

Dark clouds gathered on the horizon on the early morning of Decoration Day. While our sorrowful people were preparing garlands and tokens, to honor the heroic dead who had fallen in battle in the Wilderness, or on some such field as the Bloody Angle at Spottsylvania, the crews of the defense fleet were called to quarters and told to prepare for action.

CONDITION OF THE SEA.

With the early dawn the wind and sea increased. It was particularly noticeable to the commanding officers, that our men were somewhat superstitious concerning the result of a conflict on Memorial Day.

The Admiral had anticipated this action, and in a general order had reminded our crews that grief was the forerunner of glory, and that if all did their duty, Memorial Day would here-

after be associated in America with the greatest naval victory of the century.

Early in the forenoon watch, the enemy's fleet was sighted to the northward and appeared to be in readiness for action. Their numerous scouts and torpedo boats instantly steamed towards the shelter of the heavy battle ships. The fleet of the enemy steamed to the southeast, and it was evident that, if they accepted battle, it would take place some distance from shore. At this time there was quite a rough sea and considerable wind, which materially checked the speed of the smaller boats.

COMPARISON OF OLD TIME FRIGATES AND MODERN BATTLE SHIPS.

As our vessels approached the enemy, and saw their powerful battleships, the old sailors were impressed with the fact, as expressed by a correspondent from Kiel, "That modern navies can not reproduce the glories of the ships of the line and old fashioned frigates of Nelson's time. An old time man-of-war with her seas of snowy canvas was a thrilling sight. A fleet of such vessels, with sailors swarming in the rigging, was a spectacle for gods and men. The modern battleship, with all its defensive armor and tremendous batteries, can not be dressed for a holiday like one of the heavily rigged frigates of former days. It is a clumsy fortress in the water, without adequate facilities for decorative effect. It is an engine of war, a fighting machine, a marvel of engineering science, but with all the potency of its armaments, it has not the same power of arousing enthusiasm which the old line ships have exercised in the past. And a modern fleet, with its destructive engines and defensive resources, lacks capacity for lighting up imagination. It is an immense combination of smoke stacks, machine shops, engine houses and ordnance factories, tricked out with occasional bunting, but deficient in spectacular charm and fascination."

PREPARATIONS FOR ACTION.

The crews had no need to be told that, for the first time in the world's history, there was now about to be waged a battle of machines; and that victory would come to that nation, whose crews

could handle and control the various engines of war with the greatest skill and for the longest period.

A few weeks previous to the battle, the engineers had been given absolute charge of the men in their department, but the demoralizing work and influence of a decade of faulty organization could not be wiped out in a day.

The fire room watch repaired to their stations below, and soon the clicking of metal warned them that some of the hatches were being battened down by the carpenter and his mates. The Admiral in command realized that his success that day depended upon the efficiency of the machinery, and to prevent anything from falling amongst the moving parts of the engines, the hatches were closed. Perchance many of the firemen, who went down that day in their ships of war, had some presentiment that their coffins were being sealed, when they saw the closing of the deck openings. The ring of many a hammer was the death knell of some brave fireman and coal passer.

APPEARANCE AND CONDITION OF THE ENGINEER'S FORCE.

The engineer's force presented a particularly fine appearance. Strong men, with intelligent faces indicative of character and loyalty, comprised this assemblage of mechanics and firemen. Always the neatest and best dressed division of a war vessel, they realized the worth and importance of their own services in the impending battle. Many were continuous service men, and although they had the unqualified respect of their engineer officers, but few good conduct badges adorned their breasts. An inexcusable system, whereby it was not the province of the Chief Engineer to recommend worthy men to his Commanding Officer for this honor, had deprived these firemen of these desirable badges. Their commanders had respected them too, but, in the midst of the multiplicity of papers, they had forgotten to reward the men working below. Coxswains-of-boats and captains-of-tops, who were under the immediate observation of the executive officer, never failed to receive such recognition when deserved.

With his quick eye and wonderful judgment, the Admiral realized the condition of affairs, and then he spoke words of encouragement to these men. Machinists, firemen, and coal passers knew that this brave man regretted the neglect of previous years, and that at last the time had come when their work was appreciated. A cheer of joy and gratitude went out from the hearts of these firemen, and when it was taken up by the crew, the Admiral was visibly affected.

COUNCIL OF WAR ASSEMBLED ON ALL THE SHIPS.

The Admiral of the defence fleet had given special orders that the Executive Officer, the Chief Engineer, the Navigator and the officers of the gun divisions should, in council of war, be notified, by the Commanding Officer of each ship, of the plan and details of the proposed fight, as far as the movements and actions of each ship were concerned, so that, in the very likely case of the destruction of the interior communications, each of these officers could still act intelligently and in accordance with the prearranged plan. On this subject, it may be interesting to note the following observations of the Commission of Inquiry on the French battle ship *Magenta*, taken from " La Marine Francaise " :

" Inclosed in the conning tower, assisted by a few picked men, the Captain's whole care will be the manœuvering of the vessel; he cannot see his crew, nor cheer them by his presence and example, and can communicate his orders to them only by means of wires and pipes, the destruction of which, on their long circuit around the vessel, is open to many chances. If he has not, long before, given precise instructions to his officers; if these officers are not fully conversant with his ideas; if they have not, in their turn, instructed the crew in this respect; and if, finally, each man does not understand the details and importance of the part he is to fill, there will be, at the moment of combat, no assured communication with the Captain, and each party, shut up in a compartment of the vessel, will anxiously inquire what is taking place in the adjoining ones."

FINAL INSPECTION OF THE ENGINEER'S DEPARTMENT.

The Chief Engineer and his assistants made a final inspection of the fire and engine rooms. Provision had been made for getting the best work out of every machine, and they were in a most excellent state of efficiency. The men were kindly greeted and encouraged, and the example of their officers, in going about their duties so quietly and unconcernedly, inspired great confidence in the engineer's force. There was no piping of whistles and shouting of orders to men within speaking distance. The men were thoroughly posted in regard to their duties, and the watch bill had been so laid out, that each man knew the extra duties he was expected to perform, in case any should fall or become prostrated from the heat or overwork. Some spare tools had been placed within reach of the machinists, and all necessary stores were in accessible positions. The Emergency Watch made the rounds of the vessel and adjusted things where necessary.

A final consultation was held with the commander of each vessel. It was recognized by the several Captains that the man aboard ship, who had to be resourceful, ready to assume responsibility, and peculiarly fitted for his task, should be the Chief Engineer. In this hour of danger he was not told that he was an idler, and that "aboard ship he was a non-combatant." But he was reminded of the fact that his post was one of danger, and that upon the efficiency of his department would depend the result of the conflict. For speed is now a weapon in naval warfare, and he who controls it can look for victory. The Chief Engineer had no need to be told that, when the fight was over and the crews mustered, it would be found that a greater percentage of the firemen than of the seamen would rest that night under the surging waves of the Atlantic.

OPENING OF THE BATTLE.

Gradually our fleet overtook that of the enemy. A flash of fire, a puff of smoke, the whizzing in the rigging of a projectile, and then commenced the historic battle of Chatham.

From the time the first shot was fired, the enemy made every

effort to render the vessels of our squadron unmanageable. Shell were fired at the water line aft, with the hope that some fragment would strike a vital part of the rudder and screws, or some one of their attachments. To the great dismay of our Admiral, the *Brooklyn* was partially disabled in this way. It was found necessary to steer the vessel by means of her screws.

Some of the hatches had been battened down, and the temperature of the engine room had risen to over one hundred and fifty degrees, within a half hour from the time daylight was shut out. The annunciator signals worked rapidly. Midway between the high pressure cylinder and some auxiliary machines, the machinists stood at their posts, working the engines to bell signals.

The inspiration and encouragement, given the firemen and coal passers by the officers in their tours of observation, had much to do with the cheerfulness of the men. They were not cheered by an occasional shout of victory, which broke forth when one of the enemy's vessels seemed to waver under some disablement, or when our Admiral complimented an occasional ship for her superb work. These brave artificers performed their duties with zeal and intelligence, but the strain upon them was intense. At times, the seaman at the engine room telegraph in the conning tower pulled the lever a trifle hard, and the index pointed to the line separating two different signals. The man on watch would have to decide quickly to which order he would respond. His judgment and common sense came into play, but it required great concentration of thought and immediate decision. Breathing an atmosphere partly saturated with steam, for the drain and relief valves had to be opened occasionally to the bilge under such circumstances, these men by their devotion to duty saved the ship. Before the fight was over, one of the engineer officers fell in an apoplectic fit. And after the battle, when the excitement was over, one machinist and two oilers collapsed from the result of their terrible strain in manipulating the engines for nearly five hours.

Within three months, these men passed away, but their work on the day of battle had been glorified by a crown of martyrdom.

DISABLEMENT OF THE *MASSACHUSETTS*.

The enemy seemed to concentrate their fire on the battle ship *Massachusetts*, that name recalling, to the mind of their Admiral, the great part that Massachusetts had played in the history of our country. For a time, it seemed as if this vessel had to contend against a whole division of our opponent's fleet. The skill and courage of the Commander saved her more than once from being rammed and sunk. Two of our battle ships and several cruisers were sent to her assistance, and relief was thus given her, but just before the enemy's squadron had been made to retire, the *Massachusetts* sent up a signal of distress. The continuous shower of shell upon her armor, combined with the recoil of her own guns, had started the main stop valve joint on the starboard boiler of the after compartment. The escaping steam had driven the men from the fire room. One of the water tenders, who had been fitting a new gauge glass near this valve chamber, had been killed by inhaling the steam, and a part of the fire room force, who had entered the bunker, was missing. An engineer officer, who had tried to prevail upon the men to remain in the fire room, had been partially blinded, having groped his way midst the escaping steam to locate the impairment. Until he had found the cause, it had been believed that an auxiliary steam pipe had burst. This officer had been pulled out of the fire room by a machinist, whose accurate knowledge of the fire room passage, had made it possible for him to reach the water tight door leading into the engine room. The men from the other fire room in this compartment had been compelled to leave their station, the leak from the joint continually increasing. Communication with the other boilers had been cut off, but not until the pressure in the boilers of the other compartments had fallen. Brave men finally raised the safety valves, and, eventually, the stop valves were closed from deck. A good percentage of the men, treated that day by the surgeons of the *Massachusetts*, was found in the watch that had to battle with this casualty. The frightful roar of steam through the escape pipes disheartened the ships of our squadron, and once again the *Massachusetts* was made the center of attack. Her gallant captain fell at his

post, but the story of his fight is known to every school boy in the land. Like the *Constitution* and the *Hartford*, the *Massachusetts* will ever be regarded as one of our historic ships for the work she did that day.

EFFECT OF THE HEAVY SEA UPON THE SMALL BOATS.

There being considerable sea, the speed of the smaller vessels of both squadrons was materially reduced. The enemy, by having blockading work to do, had quite a number of transports which, at this time, hampered them. Many of their boats put to sea. Followed by the *Olympia*, with her large boiler power, quite a number of these small craft was totally disabled. The heavy sea did not affect the speed of the large cruisers to the extent that it did the smaller craft. And our vessels, with their great boiler power, were not effected to the extent that the enemy was.

EFFICIENT WORK OF THE EMERGENCY WATCH.

The picked men who formed the emergency division did excellent work on all the ships. Comprised as this body was, of men who were resourceful and inventive, they were constantly in demand. The dexterity and skill, shown by some of the boiler-makers in the use of hand tools, astonished and delighted the Commanders; the jamming of the forward turret of the flagship was overcome by the rapidity with which the obstruction was cut out of the gearing. More than one disabled fire main was temporarily repaired by fitting straps over the defective parts. By quickly fitting an alligator wrench to the spindle of its training gear, one of the large guns of the *Indiana* was again made to do service. The after smoke-pipe of the *New York* was kept in place by the ingenuity with which eye bolts were secured to the rim of the upper section.

The official reports of the several Chief Engineers and Executive Officers tell in detail of the incessant calls made upon this Division, and the readiness of resource with which this picked body performed the many services required of them.

EFFICIENCY OF THE TRIPLE-SCREW VESSELS.

The *Columbia* and *Minneapolis*, with their great speed, distinguished themselves that day, and forever silenced their critics. The numerous torpedo boats and torpedo chasers were gradually sunk by the shell of their rapid fire guns. The result of this battle showed that vessels of 7,000 tons, installed as the *Minneapolis* is with a boiler power of 20,000 horses, will in a rough sea make quick work of a nest of small craft, and that the *Pirate* type will play a specially important part in a battle between fleets.

One of the nautical guerrillas, in the shape of a torpedo boat chaser, disabled the starboard screw of the *Minneapolis*. With the two remaining screws, this vessel made over 20 knots at intervals; she was easily steered, for there was comparatively little helm angle, and, disabled as she was, in connection with the *Olympia* and *Columbia*, she did magnificent work, chasing and overhauling the transports of the enemy after battle.

All during the fight, the strain upon the Chief Engineers of the respective ships was beyond description. For years these officers had no power to reward or punish their firemen. The unmanly of the fire room force soon found out, that their comfort and convenience could best be secured by winning the favor of the Executive Officer, rather than doing their duty at their stations.

The duties of the firemen " were of the most arduous and disagreeable nature, very trying to health, temper and discipline. Their management by the engineer officers was often a difficult task even in times of peace."

INSUBORDINATION IN THE FIRE ROOM.

When the stokeholds were closed on one of our ships, and the firemen realized that if any of the crew were to go down in their vessels, there was no chance of escape for them, they insisted upon leaving some doors open, so that there might be some hope of reaching the deck before the vessel foundered. The engineer officers had the doors closed, but not before shooting the ringleaders of the mutineers. These men apparently could not un-

derstand that an engineer must have absolute control over his men in action, and that, isolated as he is, he must be ready to assume great responsibilities. The insubordination on this vessel in the fire room, resulting from a vicious system, was the greatest stain upon that ship's good name and fame, and her sinking must be attributed to the demoralization in the fire room, for, if that force had been effective, she would not have been rammed.

CONDITION OF THE ENEMY.

From one of the engineer officers who was attached to the enemy's flag ship, the following facts were gathered concerning the work of their Corps of Naval Engineers:

Even before they left Halifax, trouble had been found aboard two battleships and one of their fastest cruisers with their hydraulic piping. Night and day the mechanics had been at work overhauling the joints. The flanges had been smoothed and, where necessary, caulking of the seams had been carefully done. The entire line had been repeatedly disconnected and, wherever possible, easier bends had been substituted. Vegetable packings woven in a variety of forms had been tried, as well as the cup leather and metallic types. Incessant leaks had occurred, and up to the day the fleet had occupied Provincetown, it had been impossible to move one of the turrets on the speediest battleship; for in repeatedly overhauling this vessel, several of the flanges had been cracked. No one in the fleet had been able to repair the damage, for the flanges had been secured in a special way which required the use of particular machine tools. Several of our own ships had some of the flanges of the hydraulic piping fitted in ways equally hard to repair, but fortunately our ships had been within a few hours reach of repair establishments, where a specialty was made of this kind of work.

These ships had crossed the Atlantic just in time to encounter the equinoctial gales. From the day they took their departure from the Western Islands, until they reached the American coast, they had met continuous bad weather, and it is possible that the turrets and hydraulic outfit had in some way been impaired at the time.

Several pin holes in the pipes had made their appearance, but this weakness had been overcome by fitting eye straps over the defects. Under a pressure of six hundred pounds, a stream would issue from one of the holes, which had velocity enough to cut a person standing in front of it. A single hole was sufficient to imperil the system. Exceeding care had been taken with the cotton rubber packing of the joints, but it was found that, from atmospheric or chemical causes, the material had lacked some of the advantages which it possessed when the plant was installed. It was impossible to prevent the joints from leaking a short time after pressure had been applied. Some trouble had been anticipated with this piping, as, about ten years before, one of their most powerful vessels had met with similar disablement in the Far East.

Had not the enemy had this difficulty to overcome in two of their battle ships, the *Massachusetts* would probably have been sunk after the accident to her stop valve chamber.

Our Admiral was not altogether surprised at this news, for he well knew that it had been found necessary to renew the piping of the *Monterey*, and that experts had to be sent from the Washington gun foundry to overhaul the joints of the *Amphitrite's* hydraulic gun gear after she had been three months in commission.

IMPAIRMENT OF THE FANS.

On one of the ships having a closed fire room, serious results occurred from the stoppage of the fans. The fine dust from the floor plates was carried into the bearings and crank pins of the blower engine, and at one time, three-fourths of the fans were not in use. The repeated bell signals from deck compelled the artificers to give their attention to the working of the main engines. The overhauling of blower engines had therefore to be done very hurriedly. Orders having been received to force the fires, the blowers were speeded up again. Water having been carried over, the result was a breaking down of the plant. It was not long before the vessel's speed was reduced, and this magnificent ship, from which so much was expected, cut a sorry

figure in the fight. Better luck was had on those ships having the "closed ash pit system."

The experience acquired in this battle showed that the blower engines should not be made so light that they will not stand hard usage and slight neglect.

VERY INEFFICIENT FIREMEN IN ENEMY'S TRANSPORT SERVICE.

The enemy labored under the great disadvantage of not being able to maintain a sufficient and trained fire-room force. Their stokeholds were filled with firemen and coal passers who were inefficient by reason of their age and inexperience. They were practically boys who had been recruited from a class which had never worked in vitiated atmospheres, and when compelled to duty in the stokehold, heated to a high temperature, they soon collapsed. These youths could not do the work that had been performed by the Chinamen who had formerly done the stoking.

Our Ministers at Pekin and Tokio had urged the respective Governments of China and Japan to forbid their citizens entering the service of the enemy, and this request had been complied with. This seriously crippled their transport service and materially lessened the efficiency of their merchant marine.

The Engineer-in-Chief of the enemy's service had pleaded almost to desperation that the declaration of war be delayed until at least partly trained firemen could be secured for the transports. It was absolutely impossible for him to reason with the officials of the Admiralty. They thought that they knew more about firemen than he did. They told him that by his very nature, training and education he was incapable of looking at matters beyond his department. He was also told that his efficiency, if necessary, must be subordinated to the good of the service. This platitude and truism had no application to his request, but in connection with the slur upon his profession, it was expected to silence him. It was a costly error to that great Nation to rebuke this able man, for if his advice had been taken, the result might have been different.

This man knew that the bulk of the great carrying trade of the world had been done in vessels with Chinese firemen, and

that if they were suddenly removed, there would be no trained substitutes available.

Of all the steamship companies that enter the ports of the Far East, only three have European firemen, and even these companies have coolies assisting the white stokers. There are over sixty lines of vessels trading with these ports, so that it may be said that in one hemisphere there are practically no ships with an European fire room force. Five-sixths of these lines have Chinese firemen, and some of the stokeholds are so hot that white men cannot work in them. For years the weakness of our enemy in this respect had been known to marine engineers, but their warning had been ignored. The study of the tactics of preceding centuries had a greater charm than the solution of an important engineering question.

"Remove the Chinese from the stokeholds of our vessels and the carrying trade of the Far East passes from our control forever," said an European Marine Superintendent, who had lived over a score of years in China. This man knew that it would take them five years at least, and probably ten, to supplant the Chinese stokers by a trained force of competent firemen. There are men who believe that the task would be impossible, for the Chinese stokers live in heated stokeholds where Europeans would collapse.

The firemen of the transatlantic greyhounds are compelled to lay off at least every third trip; and to keep them up to their work, they are supplied with the most nourishing diet as well as commodious quarters.

These Chinamen had simply to be prevented from entering the Merchant Marine Service of the enemy, and their commerce received a blow which was more than serious.

The Japanese have a full realization of the aid rendered England by the stokers of the Middle Kingdom, and one of the ways the Asiatics are going to secure the commerce of the China Sea is by cutting off this supply.

A distinguished Russian officer told me that in case they ever had trouble with Great Britain, one of the first things to be done would be to drive the Chinese out of the English fire rooms. If

no other method could be found, they would declare such men pirates, and hang them upon capture. In this way, he said, we will cripple their transport service and drive much of their commerce from the ocean.

I was also told by an able British editor that the removal of the firemen would so impair the speed of their boats, that the insurance rates would run up so high, that a good percentage of the ships would have to tie to their docks.

This fire room question was a momentous one to our enemy working far from their military base.

SHORE FIREMEN INEFFICIENT AT SEA.

The most skilled firemen had been sent to the war vessels, and this left a comparatively untrained force for the transports.

It was noticed that the firemen who had previously worked around boilers in shore establishments were not efficient men at sea. They were good water tenders and possessed some skill in firing, but the great heat and limited room for working the furnaces seemed to unnerve them. It was almost impossible to make them stand up to their work. On shore, the boiler houses were large, and there was room for all manner of appliances which somewhat lightened their work. The older the shore firemen, the more unsuited they seemed for the work required of them aboard ship.

The experience of the blockading fleet, and particularly the work on the transports, showed the necessity of having some training school for firemen.

Halifax, not being a commercial center, it was found difficult to secure men there to replace any vacancies in the fire rooms of the several vessels.

CONDITION OF ENEMY'S FIREMEN.

From the time our fleet had been sighted, the Admiral of the blockading squadron had hesitated in regard to engaging in battle. There was not a ship in his fleet which had a full fire room force. There is not a modern man-of-war afloat which can do blockading duty for a month, without a good percentage

of the firemen breaking down. The men had given way under the intense strain of continuous work and the fear of torpedo attack. Boilers under steam for weeks, and worked irregularly, are bound to leak, and to keep up an engineer's department under such circumstances requires incessant work. It is true that these men had been assisted by mechanics from the repair ships, but the number of men that can be accommodated on such vessels must necessarily be limited.

With each succeeding day the strength of the engineer's force decreased, so far as numbers were concerned, and it was only because the blockade had to be maintained, and that time was diminishing the efficiency of the firemen, that the Admiral of the enemy's fleet consented to meet a squadron which was superior to his own, only so far as the health and completeness of the ships' crews were concerned.

One of the fire rooms, aboard a certain class of vessels in the enemy's service, is known to their stokers as the "slaughter house." If it is so baneful under easy cruising, what will such a stokehold bring in time of war? In one of our types of vessels we have a fire room which is not much better. How can the men be made to work in such a place?

It is said that aboard the *Yang Wei* at the naval fight of Yalu, "down in the boiler room naked coolies shoveled coal for dear life, gin was as free as water to them, and whenever a man lagged, he was urged on with blows from a thick club made of rubber belting. The draft was so intense, that a continuous sheet of flame poured forth from the funnel."

We can't drive our men in this way, but how are we to make them stand up to work that seems beyond their endurance?

Here is the way Admiral Reveillère, of the French Navy, would overcome this difficulty:

"Let not the deck officers scorn to go below in the fire room when the machinery is going at full speed. In time of war, when the engineer officers will be overworked and the firemen exhausted, it will be necessary to order below in front of the fires our strongest apprentices, in order to be able to give chase or to run. The young officers or midshipmen ought to be able to lead

them there. There, where there is danger and fatigue, is the post of duty for the officer. Formerly we did not disdain to go out on a yard arm in bad weather. We should now be able to go in front of the fires when it becomes necessary to push the pressure above the limits of the boiler, either to capture or escape from an enemy. Let everybody on board be trained to fire regularly, and every one know how much coal each furnace will burn at the grestest and at usual speed. The lowest boy used formerly to know how much the ship made by the wind or with the wind astern. Our crews have enough pride to attach the same importance to the speed of the engines, and not one of them will, therefore, dislike going below before the fires on the day of a fight, to take the place of the sick or the crippled."

This reads beautifully, but the enemy, with the best fire room force in the world, could not put such desirable recommendations into practice. A fireman is a skilled worker, not a strong laborer, and cannot be replaced so easily.

WEAKNESS OF THE ENEMY'S TRANSPORT SERVICE WHEN FAR FROM ITS BASE.

Heretofore the enemy had been regarded as a nation which had an unrivalled transport service, and one which was supposed to be sufficient for every emergency. Operating three thousand miles from home, and with an alert and aggressive opponent, was a condition quite different from that which had confronted them in previous years. The *Columbia*, *Olympia* and *Minneapolis* had captured so many of these boats, that the protection of the transports was a matter of great concern to the Commander of the enemy's fleet.

It was recalled to mind that the Japanese required 80 transports to carry the same number of men that our enemy had. But the transports of Dai Nippon worked only 400 miles from their base and were practically unmolested in their service. The ships of the Japanese were also coaled by people from shore. The enemy operating off the New England coast had to coal at sea. The Japanese practically did no blockading.

The firemen of many transports broke down under the severe

work exacted of them. With crowded decks, they neither had the privileges nor the comforts heretofore given them. Our *Minneapolis*, *Columbus* and *Olympia* had no trouble in capturing the fastest of them. As the transports had not done the work that was expected of them, the enemy's fleet went into battle with more than one vessel lacking a sufficiency of stores and supplies.

DISABLEMENT LIABLE TO OCCUR.

During the action, the engines of the several ships were used intermittently, not only at full speed, half speed and at varying speeds of backing, but at progressing and decreasing speeds ahead. The machinery is built for such work, and with care, should not suffer when subjected to such strains. But, in time of excitement, the men on watch will hear the telegraph signal repeated by startling orders from above, and in order to obey quickly, valves will be suddenly opened. Starting up quickly will cause the boilers to foam and, if water gets in the auxiliary line of steam piping, there is going to be trouble with some of the dependencies of the main engines.

Some of our ships have single engines to drive their circulating pumps, and these are liable to become disabled if water is carried over. The same trouble can be expected from the independent air pump. These dependencies must be placed low in the vessel where they can be easily manipulated, and as separators, traps and such contrivances are at times unreliable, their working will be seriously impaired when water reaches the pipes.

EFFECT OF SHOT AND SHELL.

There is another class of accidents which may happen for which the machinery should not be held responsible. I now refer to accidents caused by shot and shell, by torpedoes and by ramming. A shot or shell in the machinery space, a torpedo under the ship, or a good blow from a ram would probably disable the ship and, in most cases, the only thing to do would be to get out. There are other accidents which may arise from shell bursting over battle gratings. Suppose a shell were to burst in the armored portion of the smoke pipe, or just over the

grating, the concussion or force of the blast might easily tear away some of the uptake, and interfere seriously with the draft. Again, should a shell burst over some of the other hatches, which must be open for ventilation, splinters from the shell would come through the gratings and might cut some of the steam pipes, filling the compartment with steam, and disabling a part of the machinery which was supplied by that pipe. It would not require much of a splinter to pierce the main steam pipe. This would disable, or rather might disable, the main engines, depending on whether there was more than one steam pipe and on the seriousness of the accident. These splinters might do other damage, but I do not think they would be likely to do much harm to the larger parts of the machinery.

EFFORT TO DISABLE OUR PROPELLERS.

The position of the propeller renders it liable to accident, and more than one ship was disabled that day from injury to the screw. Floating objects will break the blades and shafts of the propellers, and the machinery, when subjected to unusual shock or strain, may bring about the same result.

Our enemy's Commander-in-Chief expended at least one fast torpedo boat in the effort to disable one or both of the *Iowa's* propellers. A bold attempt was also made, under cover of the smoke, to carry on the bows of a swift boat a wire netting, which it was believed could be entangled in a wing screw of one of our large ships. All through the fight, the disabling of a propeller of our battle ships was a feature of the enemy's strategy. The Admiral believed that any battle ship, with one of her two sets of engines disabled, and carrying a helm angle that materially interfered with her manœuvring powers, was little better than a cripple, so far as offensive work was concerned.

Our Commanders, with their intimate knowledge of the currents off the New England Coast, were able to manœuvre the vessels in such a way that, except in the case of the *Minneapolis*, their propellers were not disabled by the maritime pests in the shape of rapid small craft.

The breaking of a propeller blade in itself may not be a

serious casualty. If it is followed by irregular working of the engines and subjecting the machinery to shock, a broken thrust shaft may be the consequence. Losing a blade throws the engine out of balance, and machinery is then subjected to irregular strains. With a heavy sea prevailing, and a propeller in this condition, a fracture of the thrust shaft need not be surprising. Partly submerged objects in a narrow channel may do great damage to the propellers of war vessels by breaking off the end of their blades.

Our Admiral had carefully warned the several Commanders to look out for floating objects, and that the protection of the propellers was a matter of serious importance.

MISTAKE IN HAVING DYNAMOS FAR REMOVED FROM MECHANICS.

That policy of ours, which placed the dynamo rooms as far as possible from the boilers, brought distress to more than one of our vessels. The insulation of the wires is not impaired on other ships by placing the plant within the engine or boiler compartments; and, as we use the best insulated wire that can be purchased, it is fair to presume that we can do as well as other people in this respect. Our ships went into the fight with a long line of piping between the boilers and the dynamo engines. That mysterious force, which can be so easily understood, has its generator in a part of the vessel where the engine force cannot assist in its maintenance, and where skilled mechanics cannot put it in order when disabled. We paid dearly for this work in this battle. Very early in the fight, two of the battle ships had the steam pipes of the dynamo plant disabled by metal splinters. Concussion of striking projectiles, on another ship, started the joints in the long line of piping on the berth deck and, in general, we repeated the performance that took place at the Yalu, where every electrical device was out of order when the contest was over. The enemy had better luck with their electrical plant, for their dynamos and attachments were better protected and nearer the boilers. Their skilled artificers of the engine force supervised and directed the running of their dynamos, as the engines were within reach. Our machinists, being in another compart-

ment, could not assist when called upon for aid. The emergency watch, however, made temporary repairs whenever it was possible to do so.

RESULT OF THE BATTLE.

This lecture simply tells of the responsibilities and duties of the Corps of Naval Engineers. It is not an account of that great naval conflict which was fought off the bold coast of New England, where we gained the great victory which placed the laurel crown upon the brow of the greatest Admiral that America ever produced. Our enemy was vanquished. From Bar Harbor to Block Island the coast was safe. When the story was told across the water, our enemy soon realized that, with the best engineer force of any nation in the world, their steam department had brought their ships to grief.

The disadvantages under which the engineers and firemen of the blockading fleet labored, compared with those of our defense fleet, were too great to be overcome. There were no immediate reliefs to take the place of the sick and exhausted. There were no auxiliary repair stations to overcome casualties. There were not thousands of available laborers ready to coal the ships. There were no peaceful harbors to anchor in during the fury of the gale, or when great repairs were needed. There was a vigilant and aggressive fleet for our enemy to watch, and the defence fleet had at its command, within a few hours, the resources of the best machine shops in the world.

As the battle of the Chatham had been a contest of machines, it was not surprising that we won.

Their engineers and firemen (and there were none better afloat) had simply been used up by the fewness of numbers, the inexperience of many of the firemen, and by excessive work before the battle began. That mighty nation then looked for the cause of the collapse in the motive department of its vessels of war. It was found in a vicious organization which had not done justice to the Engineer and his force of men. Then a structure fell, whose foundation stones were tradition and conservatism; and ever since, in that service, the purple stripe between the bands of gold has received the recognition it justly deserves.

This battle also aroused our Government to the importance of the engineer force on board ship. Countless facts were then forthcoming of the vital necessity of extending the naval engineers' work. It was then realized that on the engineers primarily rests the fighting efficiency of every navy.

A reorganization was effected which was regarded, by those who had been indifferent to the development of machinery in vessels of war, as revolution.

Fourth Lecture.

THE WORK OF THE CORPS OF NAVAL ENGINEERS AFTER BATTLE.

"Rejoin my flagship in three weeks," signalled Vice Admiral Ito to the commander of the *Matsu-Shima* as she steamed for Japan after the battle of the Yalu. With moderate steaming this vessel ought to have reached a dockyard in two days. Allowing three days for docking, (which is more than the average time taken in Japan when no repairs are made to the hull or propeller,) and at least two weeks were given for repairs. The only impairment, which seriously interfered with her efficiency as a fighting machine, was the disabling of the controlling valve of her 65-ton gun. The other repairs were scattered and admitted of a large force to work upon them.

The *Matsu-Shima* will ever be regarded by the Japanese as the historic ship of the Yalu, and for which Admiral Ito had a special love, for upon her decks he had won his great victory. It was upon the military mast of this vessel that the kite flew, which brought so much happiness to the sailors of Dai Nipon's fleet, and which was regarded as the harbinger of success. There were other good reasons why the Admiral was anxious to have the vessel join him at a very early day and, in giving three weeks for repairs, it is fair to presume that it could not have been done in less time.

This will give some idea of the delay experienced in making repairs to a modern cruiser. The workmanship of the several parts is of the highest order, and unusual care is taken in assem-

bling them together. To withstand the pressure and strain which the parts are subjected to, the best of material must be used, and the design must have much to commend it.

Many people have written of the strategy and tactics of a fleet in the piping times of peace and fair weather cruising. In one of the publications of the U. S. Naval Institute, Fleet Engineer George Quick of the Royal Navy writes of "The Organization of the Naval Engineer Forces." He particularly dwells upon their duties "*in the hour of battle and the week afterwards.*" This earnest and talented officer has contributed one of the best and most important monographs that has ever been issued by a service journal. And yet his article stands out almost alone, as the one contribution which has been unnoticed and not deemed worthy of discussion.

His views are sound, and our great land will yet profit by his warning, for he tells us things we should all know. He writes with an earnest affection for our Navy, although in a service which may one day meet us in battle. But he assails too strongly, although very kindly, the traditions of the past, and therefore his able article has been unnoticed.

A TRIFLING IMPAIRMENT OF MACHINERY MAY DISABLE BATTLE SHIPS.

In speaking of the impairment aboard war vessels, Mr. Quick says:

"Let me give one small example of those things which are occurring every day in all navies.

"On the 13th of July, 1891, during target practice on board H.M.S. *Trafalgar*, the locking bolt of the after turret was broken, and the turret was practically useless for three days, although the ship's artificers worked night and day at the repairs. Here we see one-half of the fighting power of a ship of 11,940 tons and 12,000 horse power disabled for three days by the breaking of a single bolt. But if the breaking of a single locking bolt disables the half of the fighting power of a 12,000 ton iron clad, and the repair of that defect requires the labor of the whole of the ship's artificers for three days and nights, what may we ex-

pect when a ship has been engaged for an hour with an enemy of equal fighting power? How many mechanics will be required to repair damages after one heavy shell has exploded inboard? This question is easy to ask, but not so easy to answer."

With such facts before us, it must be recognized that the breakdown of the engineering department during action means the total loss of the ship, or its usefulness for offensive work completely destroyed.

If any part of a shackle is defective, the result may be as serious as the breaking of the strongest link in the chain. The failure of the piston rod to have a well rounded fillet on its shoulder, may cause the same wrecking of cylinders that occurred on the *Ericsson*. The blowing out of a single tube may disable a boiler and interfere with the efficient working of others.

NECESSITY OF HAVING RELIABLE MACHINERY.

The distinguished naval architect, Mr. W. H. White, in a paper read before the Royal Society, expressed the opinion that modern ships will not stand more than one well-contested engagement, and many naval officers share this view. Thus declares the "Army and Navy Gazette," less than a year ago, and after the battle of the Yalu:

"To prepare for such a day, our vessels should be designed accordingly. There should be no stinting of weights in the engine room. Rather than do this, decrease the width of the armor belt and cut down the bunker supply. A leaky boiler and a poor condenser on a cruiser will reduce the steaming radius more than the removal of a hundred tons of coal.

The Engineer-in-Chief of the Navy, in his uncompromising struggle against the reduction of machinery weights, is fighting the battle of our Commanding Officers rather than that of the Chief Engineer, and upon this question, the influence of this college should be exerted in supporting him.

Would that policy commend itself which would cut down the weight of a gun and its mount about 10 per cent., after the experts had carefully submitted estimates?

NECESSITY FOR PROVIDING FOR REPAIRS.

Naval experts have now commenced to realize the necessity of making provision for executing repairs more promptly. The equipment of floating workshops is an outcome of the repeated breakdowns of war vessels, due to crowded machinery with excessively light parts. That inexcusable fad, to make lighter machinery than one's neighbor, is now going out of fashion, although we can rejoice in the fact that the custom did not have a strong foothold in America. It is no longer good form to be an advocate of a half dozen kinds of motors aboard a single ship, for immense repair bills and disabled machines are the sequence of having steam, anhydrous ammonia, compressed air, hydraulic accumulators and dynamos aboard the same vessel. The full measure of the specialist has been taken, and most of his projected machines now do not get beyond the designing room, for the tendency is to simplify the auxiliaries and give each one more room and increased weight for its installation. This makes the several parts more accessible for overhauling and decreases their liability to become impaired. In designing machinery for war vessels, facility for examination and repairs is going to be considered a greater factor than it has been heretofore. That vessel is no longer regarded as useful which is constantly under repairs.

In order to be prepared for battle and to quickly recover from its effects, war vessels must be constructed for continuous service and not for trial trips. In building the several types, the machinery should be made sufficiently strong, and more room should be given for its installation, which space could be found by taking part of the quarters of the officers. If this were done, the vessels would be more serviceable in action, and there should be fewer repairs to make after battle was over.

In the upbuilding of a navy, therefore, types and classes of vessels should be constructed; there should not be an aggregation of individual ships, which embody the ideas of earnest specialists, but which have no relation to a comprehensive plan and which require months to repair when disabled.

There are many strategic reasons why there should be such

classes, but from an engineer's standpoint the following are sufficient:

(*a*) Defects of design in the machinery would sooner be discovered and overcome.

(*b*) With men thoroughly acquainted with the fittings of several ships, it would be possible to make several changes in the personnel by which the engineer's force could quickly be reorganized after battle.

(*c*) The best method of maintaining the efficiency of the department, making necessary repairs and doing the general overhauling, could be developed.

(*d*) From several permanently-disabled vessels, all but one might be rendered serviceable after battle, if the impairment was in the machinery.

(*e*) Fleet drills and manœuvres could be carried on with more efficiency. Reliable uniform speeds could be secured more easily and rapidly. And the Admiral in command could get better work from his fleet, for his strategy and tactics could more easily be carried out.

It is true that the individual commander, by his skill, courage, and strategy, may render great service to the State and bring glory and renown to his career. The destiny of nations, however, will be decided by battles between fleets and not engagements between ships.

This lecture, will, therefore, treat of the work to be done after battle with a fleet composed of types of vessels, rather than tell of the ingenuity of special individuals. It will deal with this particular problem, as this is about the real condition of affairs.

It requires no great imaginative powers to believe that the rapid repair of the vessels of a fleet will increase the importance of a victory or weaken the force of defeat. And upon the professional skill and directing talent of the Naval Engineer will depend the success of this work.

WHERE REPAIRS SHOULD BE MADE AFTER BATTLE.

A few days before the enemy had been attacked, the question of *where* and *how* the repairs could be made, had been carefully

considered by the Engineer-in-Chief, the Admiral in command of the Defense Fleet, and the Secretary of the Navy. Should the vessels be sent to a Navy Yard? *How* should they be repaired? These important questions were carefully inquired into.

It was determined not to send any vessels to a Navy Yard, except those which required docking, for the following reasons:

Time was of the utmost importance in getting the fleet ready for sea again, and the history of the Navy Yards, in previous emergencies, showed that work could not be expedited there. Industrial engineering methods are incompatible with official routine, and a vessel once within the grasp of a military clerical system had to submit to vexatious delays. There were many other good reasons for sending the fleet elsewhere than to Navy Yards.

Until the conflict was finished, it would be impossible to tell how extensive the repairs might be, and it was almost a certainty that private firms would be called upon for assistance. These establishments could not work in co-operation with naval plants. Their methods were altogether different, and there could not be harmonious and efficient commingling of their forces. This was unhesitatingly told the Secretary of the Navy.

Another fact, which influenced the decision, was the time that it had taken the North Atlantic Fleet the previous year to overhaul at the Navy Yard, and the fraction of that time which it had taken sister ships on other stations to do the same general work. The Engineer-in-Chief showed so conclusively that the repairs could be made more promptly in Narragansett Bay, that his recommendation was endorsed by the Admiral of the fleet.

Considerable preparation had therefore been made for the reception of the vessels, and a strong corps of naval engineers and scientific mechanical experts had organized the various auxiliary repair stations and machine shops into one great plant, where all worked harmoniously in common.

Except the vessels which required repairs to their hulls and propellers, our victorious fleet steamed to Narragansett Bay and the several ships immediately commenced making repairs.

Nearly every town and city on Narragansett Bay is within two hours of Boston or Worcester by rail. Within three hours, nearly every manufacturing city in the Blackstone and Connecticut Valleys can be reached. The forts at Newport would deny an enemy entrance to the Bay; and innumerable small boats could communicate between the fleet and Providence with impunity. Within two weeks, a solid built-up crankshaft could be constructed in Providence for a small cruiser. Time will not permit me to tell of the advantages this Bay would have for repairing the machinery and fittings of a fleet.

ENGINEER-IN-CHIEF MELVILLE MADE DIRECTOR-GENERAL OF REPAIRS.

From the auxiliary naval repair stations, from the manufacturing cities and towns along the Blackstone and Connecticut Rivers and from New York and its environs, thousands of the best mechanics in the world were sent to the vessels. Engineer-in-Chief Melville, by order of the President, was made the Director-General of Repairs. This appointment was received with unusual favor by the country, for one of the enemy's greatest engineering authorities had declared, that Engineer-in-Chief Melville was the ablest Chief of any Manufacturing or Constructing Bureau that America ever had in her Naval Department. Our people remembered that, even as a boy, he had been a leader, for before he was eighteen years of age he had designed and constructed a breech-loading gun; that during the Civil War he had rendered important service, for he had originated the idea of a protective deck; that he had been particularly commended for his skill, ability, and readiness of resource on board the ill-fated *Jeannette;* that he had shown himself great in his unparalleled search for De Long in the Lena Delta; that he had been greater still in the rehabilitation of the Navy as Chief of the Bureau of Steam Engineering and as Engineer-in-Chief of the Navy. And the Nation believed that his highest greatness could be reached, if his energy and matchless engineering talents were directed to the restoration of a crippled fleet and the captured cruisers and battleships.

HOW THE REPAIRS WERE MADE.

The repair ships *Fulton* and *Corliss* reached the fleet within a few hours. Additional telegraph and telephone lines had been established within a day, the military telegraph engineers having put up lines in a manner that had astonished even the officials of the Western Union Telegraph Company. Directed by the genius of able electricians who had volunteered their services, there had been established in an incredibly short space of time, as a gift from the great electrical combine, a powerful electric light plant, which permitted the prosecution of the work at night. From all along the coast, the scouts and Sound steamers brought tools and supplies. Under the inspiration of several Fleet Engineers, and such men as D. H. Thompson and Gardner Sims, of Providence; S. B. Whiting and Asa Mattice, of Boston; Francis A. Pratt, of Hartford; C. W. Moore and Horace Lee, of New York; D. A. Tompkins, of Charlotte, N. C.; John Fritz, of Bethlehem; Coleman Sellers and J. J. de Kinder, of Philadelphia; and George W. Dickie, of San Francisco, Engineer-in-Chief Melville soon brought order out of chaos. There was not a machine shop in New England whose proprietor was not willing to turn his establishment into a naval repair station. Providence and Pawtucket, with their thousands of skilled mechanics, did the bulk of the work. Every small order was duplicated at different shops, and this was found an excellent method of pushing work. Many of the torpedo boats were repaired at Bristol, the genius of a Herreshoff personally superintending the direction and scope of the work.

REGRET THAT NO NAVAL CONSTRUCTOR HAD BEEN IN THE BATTLE.

During the progress of the repairs, it was greatly regretted that not a single Naval Constructor had been aboard any of our vessels participating in the battle. The Executive Officer, who was in charge of the Construction Department, had important duties to perform in assisting the Captain to fight the ship. Many questions relating to the principles of naval architecture had, therefore, to remain unanswered at the time.

The enemy, however, had naval constructors aboard several of their large ships, and they furnished valuable information to their naval authorities, which would have been of inestimable benefit to the Engineer-in-Chief, could it have been secured during the few days following the battle.

The mistake in not sending the constructors to sea having been recognized, one was ordered to each of the large vessels. The same success, which had attended the detailing of the ordnance and engineer designer to sea-going ships, was afterwards found in the case of the constructors. Particular improvements were noticed in the ventilating arrangements, in the improved facilities for coaling ships, hoisting boats, cleaning bilges, rigging gangway ladders, and in the location of cargo ports.

Not having seen anything of the fight, many questions relating to the repairs, which should have come within the province of the Constructor, had to be solved by the Naval Engineer, whose experience in the battle made him competent to decide intelligently.

SPECIAL WORK OF THE CHIEF ENGINEERS.

The great work of the chief engineers and the assistants of the several ships was to overlook the repairs and suggest remedies and improvements. Their services at such a time were too valuable to give their attention to any single impairment. The limited room for working, and the many local difficulties to be overcome in making repairs and doing general overhauling, astonished the mechanical engineers from shore. They realized then, more fully than ever before, the responsibility connected with the efficient maintenance of the motive department of a war vessel.

Vise benches, drilling and punching machines, anvils and forges, made a sad plight of what had once been snowy decks. No injury was done to them, however, as they had been covered by light flooring. To see the work done on these decks with hand tools, reminded many of the time when there were but few machine tools, and when it was said that such firms as Fletcher, Harrison & Co., had built the machinery of the North River

steamboats on the sidewalks of New York. Bed plates and valve seats were faced in those days by experts with hand chisels, and equally as good work was done on many of the ships of the fleet.

Loyally and patiently the shore mechanics worked. Within the cramped quarters of the back connections, the boiler makers fitted patches. For hours the machinists strained themselves in scraping the linings of valve chests. The fitters, at the peril of their lives, removed and replaced overhead piping. Conscientious men crawled under cylinders and boilers to clean bilges and keep the boiler shells in a state of efficiency.

EXCELLENT WORK OF THE TRIPLE-SCREW SHIPS AFTER BATTLE.

For three days after the battle, and while the other vessels of the fleet were being repaired, the triple-screw ships *Columbia* and *Minneapolis* were cruising off the New England coast, capturing transports and scouts, which had been sent from Halifax and which had no knowledge of the battle. Even with her disabled starboard screw, the *Minneapolis* did brilliant work. From the time a prize was sighted until its capture, the *Columbia* had no difficulty in steaming 21.5 knots; the *Minneapolis*, with her two engines, maintained a speed of nearly 19 knots.

The remarks of Admiral Fournier, before the French Special Parliamentary Commission of Inquiry, undoubtedly reflect the views of our people in regard to these triple-screw vessels. The Admiral is thus officially reported: "Wisdom should order us to abandon, as soon as possible, the construction of these ruinous mastodon battleships. The type of war vessel most useful is that of the triple-screw vessel *Dupuy-de-Lôme*."

He also said: "The naval battle of the Yalu proved the truth of the following conclusions:

"1st. The capital advantage of speed.

"2d. The superiority of rapid fire guns over heavy guns.

"3d. The uselessness of heavy armor.

"We should insist upon *speed*, which is the weapon, par excellence, of modern war ships."

FRENCH PRAISE FOR THE TRIPLE-SCREW CRUISER.

The most glowing, and at the same time the most disinterested praise of the *Columbia* was published in "La Patrie," of Paris, on July 12, under the signature of its editor-in-chief, Mr. Lucien Millevoye. He was formerly a Deputy in the French Chamber, where his speeches and assiduity to his legislative duties increased the popularity he already enjoyed as a patriotic and clear-headed statesman. "The fetes of Kiel," says M. Millevoye, "will have, perhaps, as an unexpected consequence, a renovation of the French Navy. Do you know what our sailors have admired especially in the German waters? It was not the pomp displayed by William III, to dazzle them; it was neither the golden eagle of the imperial helmet nor the theatrical show of German power.

"What has struck France and all Europe with surprise, mixed with fright, is the speed of one of the vessels of the American fleet. The cruiser *Columbia* has manœuvred before all the congregated squadrons with marvellous agility. This is, indeed, the great war instrument of the naval fights of the future. What a strength in the hands of the hardy captains of the sea! Maritime war will be greatly changed by it. That vessel, the *Columbia*, will be able to accept or refuse combat, according to its wishes. It will thunder forth shot and shell, or run away at will. It can, with impunity, cover the surface of the ocean with ruins and wrecks, or laugh at the avengers sent to pursue it. The European Nation which would have the foresight to create a large number of those terrible cruisers would be unassailable, invulnerable and invincible."

NECESSITY OF KEEPING SHIPS ON AN EVEN KEEL.

One of the lessons impressively taught during the progress of the battle, and which caused certain work to be done during the course of the repairs, was this: That keeping ships on an even keel may have an important bearing upon the efficiency of a vessel in action. There are several causes which may list a ship quickly, and unless special provision is made to overcome such accidents, it may be a question of hours before the vessel can be

put on an even keel. A list of ten degrees would expose the plates below the armor, and in this way a battleship might be sunk by the rapid-fire gun of a torpedo chaser, or a gun boat. Anything happening to either boilers or bunkers on one side might cause the list. There are several causes which might make it impossible to use coal equally from both sides of a vessel. Leaky tubes, the blowing out of a rivet, the breaking of some attachment to the shell, may all cause the water to run out of a boiler. The impact of the heaviest shell upon the side armor may start the joints, or rupture the steam and water piping, and boilers will undoubtedly be disabled in this way. Trimming tanks being a necessity, they were so placed that they were under the control of the Chief Engineer. They were connected to the main circulating and other pumps, so that they could be quickly emptied or filled. Every longitudinal bulkhead had some contrivance, whereby communication could be instantly established between the compartments which they separated.

CONDITION OF TORPEDO BOATS AFTER BATTLE.

An examination of the captured torpedo boats showed that the boilers and engines had been forced to their utmost. A few of the grate bars had been melted down, and the tubes leaked considerably from the forcing which they had been subjected to. In the efforts of the boats to escape, the working pressure had been exceeded, and the blowers had been run at an excessive speed.

Driving these small boats into a heavy sea had subjected the engines to shock. The anti-attrition metal had run out of one of the crank pins and several bearings. Some of the discharge valves of the air pump had carried away, which had greatly impaired the efficiency of the condensers.

The condition of the engine and fire room force was pitiable. For nearly a month these men had been under a great strain, both physical and mental. The long trip from Halifax had severely taxed them and, after reaching the Massachusetts coast, their work was not lessened, for the boats were kept on the go constantly in doing messenger service.

The character of the work performed in the engine and fire room of such boats has been told by Mr. John I. Thornycroft, who is the peer of any builder in the world of such craft.

Personal and financial reasons would prompt him to declare that this work was within the ability of the average man, but Mr. Thornycroft speaks plainly to those purchasing boats from him.

WORK OF FIREMEN AND MACHINISTS ON TORPEDO BOATS.

In a recently delivered lecture on torpedo boat destroyers, Mr. Thornycroft referred to the excessive work performed in the engine room. A portion of his remarks, taken from "The Engineer," London, are here given:

"Speaking of the firing, he said the stokers have to exert themselves much more than when firing the ordinary slow working boiler, for when the boat is running at full speed, if the crew is divided into two watches, it would mean that each man must stoke about 600 indicated horse-power of boiler, which is many times the ordinary rate of working and necessarily requires very good men. Again, as it is important to run the engines very fast, it may be interesting to consider how the artificers in charge of them are taxed by this necessity, and compare the running of torpedo boat engines with the engines that were used in the first steam vessels, which made few revolutions in a minute, examples of which are still to be found in tug boats, for which they are suitable.

"If we turn from the comfortable working heavy engine of the tug or river boats to the high speed torpedo boat engine working at its highest power, we then note that the sound in the engine room is confused by the addition of a number of auxiliary engines, each adding their own peculiar series of sounds to the noise of at least three cylinders of the main engine, and all these engines making a confusion which is further complicated by the fact that the auxiliary engines in their rate of working keep no constant ratio to each other or the main engines; they may be considered as part of an orchestra having a separate conductor for each instrument. Now take the next important sense for the engine driver, feeling. The engines are revolving, say

400 revolutions in a minute, and the important moving parts must be touched by the fingers and any change of temperature detected promptly. If this is not done, heating may ensue, which may oblige the engines to be stopped. In this rapid working, the eye is even put to a great disadvantage. The motion is so rapid that no particular position of any working part can be assigned to it, while spray of water and oil is thrown in the eyes and the vision temporarily impaired. However, this description only applies to running at the highest speed.

"At full power the firing scarcely ever ceases, and the forced draft gives such a high temperature in the furnaces as to render the light blinding and painful to the eyes, making the use of colored glass necessary to protect the eyes when examining the furnace to see in what part the fuel is most required. The space for stoking is limited, and the coal bunkers being small, cannot afford convenient room for the coal being rapidly trimmed from them. The very large amount of air passing though the stoke-hold causes coal dust to be carried about so as to be most unpleasant. In all this dust and hurry the water level and steam pressure must be attentively watched, and we owe much to our stokers for performing these duties, which are of the first importance for the speed and safety of the boat."

CHANGES MADE IN TORPEDO BOATS.

In writing unofficially, the Naval Engineer Inspector of the *Ericsson* made some excellent suggestions in regard to the design and construction of torpedo boats and their machinery. In view of the fact that something sad is always happening to such boats of every nation, his views were carried out in repairing the boats which took part in the battle. His ideas upon the subject, strengthened by personal experience during the accident to the *Ericsson*, were as follows :

1. In designing torpedo boat machinery, the great risk to men below should be uppermost in mind. The great watchword should be, the least possible number of pipes. It would be better to dispense with pipes that could only be used in a remote contingency. No piping should be installed which does

not directly influence the speed. In short, one pipe for many services, not many pipes for one service. The pass-over steam pipe on the *Ericsson* had never been used during the twelve trial trips.

2. On the steam pipes from the boilers, on the engine room side of each fire room bulkhead, there should be fitted a butterfly valve to be worked from deck; a man to be on watch with orders to throw down the lever on the instant of an explosion. No time was wasted in shutting the *Ericsson's* valves, yet the time consumed in doing so was appreciable.

3. The necessity of an open hatch over the whole length of engine room should be appreciated and provided for. The structural strength necessary should be given by cross beams; a cover, to be fitted when necessary, could always be carried, and the hatch made strong enough to withstand the shock from any sea. Objection might be made, but the lives of men must be of more consideration than inexcusable precedent. A plate at the forward end of the engine room was off; size two feet ten inches by four feet six inches. The course of the steam was directly up and forward, and much came through this opening. Had this plate been on, matters would have been worse. Had there been a complete open hatch, matters would have been much better.

4. The great danger from explosion, besides scalding, is the inhalation of steam. The old-time rule in case of an explosion is to get flat down and grope out. Hence, air passages or holes should be provided for, which, in case of an explosion, could be immediately opened from deck, thus allowing the whole volume of air from the fire room blowers to be sent along the engine room floor plates. The broken pipe will always be high up, and the great volume of air suddenly thrown in at the bottom of the engine room, would unquestionably be of benefit to men fighting for their lives. This idea, in connection with the open hatch, must appeal to everybody.

5. The form of ladders and their location in the boat should be a subject of great thought and care. They should be fitted in the most available space for reaching the deck.

WORK AFTER BATTLE.

In addition to the repairs on the machinery and boilers of the disabled vessels, there were other important things to be considered in getting the vessels ready for sea. The experience acquired during the conflict caused many changes to be made in the design of minor parts, and the working out of details was no easy task.

The new men had to be instructed in the performance of their duties. When it is remembered that the *Texas* has over seven hundred valves and twenty-five miles of piping, one can get a faint idea of the intelligence and ability of the machinists who are expected to successfully operate the many contrivances.

Even before the fleet started for Narragansett Bay, an additional force of firemen and machinists from the other vessels had been placed on board the *Columbia* and *Minneapolis*, in order to help bring home the prizes which should fall within their grasp.

It was night and day work with the engine room force. Men who are working out important applications of mechanical principles cannot lay down their work and peacefully fall to sleep; but restlessly the brain continues to work out the solution even after the eyelids close.

USELESSNESS OF REPAIR VESSELS TO A DEFENSE FLEET.

This month's experience proved that repair ships for a fleet, operating in home waters and in close proximity to great manufacturing establishments, were of but little use. If they carried machinery they crowded out the men. The routine work of the ship had to be carried on and she had to steam at a fair speed from place to place. There were numberless things which could be secured on shore to hasten repairs, which could not be obtained on the repair ships. The number of fittings connected with a vessel like the *New York*, with her 100 steam cylinders of various machines, runs up in the thousands, and at times it must be necessary to secure special parts from the manufacturers to make repairs. Skilled mechanics, who were experts in the management of machine tools, were useless in the fire room and, in their ignorance of man-of-war rules, they were constantly

violating regulations. Vexatious delays occurred in securing and handling material, and altogether the experience with the floating workshop was not a success.

It was afterward said that our enemy found them very useful in their fleet operations, under conditions where time was not a factor in the matter.

The repair ship was designed at a time when it was believed that vessels could be self-sustaining in regard to repairs. Time was not regarded as such a supreme factor as it is now known to be. They may be useful for a blockading fleet; as store-ships they are valuable even to a defense fleet.

DIFFICULTY OF REORGANIZING THE ENGINEER'S FORCE AFTER BATTLE.

One of the important questions that arose after the battle was the reorganization of the engine and fireroom watches. On every steamer afloat there is some special trouble, some machine or valve, either in the engine or fire room, which requires special skill or knowledge on the part of some one to overcome or attend. The failure of this auxiliary to work may have an important effect upon the efficiency of the main engines. There are some things which cannot be told; they must be acquired gradually by experience. If it were fully realized how skillful, resourceful and patient a good water tender should be, these men would receive more consideration than is now accorded them. If it should be our policy to use water tube boilers, then the duties of the water tender will require an even more efficient man for this work than in the past.

From the deck force, men may be found to relieve the second class firemen and coal passers; but the machinists, boiler makers, coppersmiths, oilers, water tenders and first class firemen can not be secured from the seaman contingent. That day has passed when the average oiler could relieve a machinist. On a modern war vessel, a boiler maker might make a whole cruise without doing any work in the engine room.

So long as we act upon the defensive and are within a day's reach of New York, deficiencies in the engineer's force may be made up.

DANGER OF AN INSUFFICIENT NUMBER OF ENGINEERS.

The error of that policy, which has permitted the best machinery in the world to be neglected by having an inadequate force of naval engineers, was soon evident. The percentage of engineers who had become incapacitated, or had gone down in their ships, was greater than that in any other Corps.

The intense heat of the department, the strain of controlling and directing men who were worn out with toil, the shattering of their constitutions by the impact of shell upon the side armor, and the concentration of thought in overcoming impairments and casualties, had played havoc with the commissioned officers of the engineer's force. The few engineers, who had been on duty on shore to supervise important work, were sent to the fleet as the reliefs of those who had been exhausted.

Exceeding difficulty was found in making up the engineer's complement. It was only done after the passage of special laws, which permitted the Engineer to give the full measure of his services to the Government.

AN ENGLISH NAVAL ENGINEER WRITES UPON THIS SUBJECT.

"The number of engineer officers has been cut down very low in the British Navy and still lower in the U. S. Navy. I say they have been cut down dangerously low, because in war times a very slight accident may disable the two or three engineer officers and leave the engineer department entirely headless."

VITAL NECESSITY OF REPAIRING QUICKLY.

It is impossible to overestimate the importance of the speedy repair of the machinery of ships of war after an action, for the gaining of only a few hours, in effecting repairs after battle, may decide most important naval operations following upon either a slight or severe engagement.

It is not a good argument to say that our ships will carry as many artificers or mechanics as foreign ships, and that consequently there is no need to increase the staff of mechanics on board our ships. For if two similar ships engage, and each re-

ceives similar injuries, so that they are compelled to cease fighting and withdraw for repairs, then if one of these ships carries, say, only thirty skilled mechanics for effecting repairs, whilst the other carries sixty mechanics, the latter ought surely to be in fighting condition first, and must assuredly capture or destroy the former.

The sting of a defeat might be removed by a defense fleet which made speedy repairs, for, with the aid of workmen from shore, the ships might be put in readiness so quickly that the blockading ships could again be attacked before repairs could be effected by the limited number of overworked machinists on board those vessels.

The New England coast, although it would be a rich prize for a hostile fleet, has elements of strength in its manufacturing establishments which may play an important part in a naval conflict.

AN ENGINEER'S WAR SHIP.

And when the rewards were distributed to those who had rendered service to the fleet, a strong public sentiment demanded that the Director-General of Repairs and the Fleet Engineer be signally honored. These men then said, that as a grateful country had recognized their knowledge of the requirements of a modern war vessel and fleet, that they be permitted to build what should be known to all the world as an Engineer's ideal ship of war. It would be one that would do the work which was expected of her.

Upon this subject the greatest engineering paper in the world had thus spoken: "Miles of letter press have been printed and published and read and discussed concerning the construction and qualities of ships of war. We cannot call to mind that any of these disquisitions, or treatises, or papers, or books have emanated exclusively from the brains of Engineers. Of course, without the aid of the Engineer the modern war ship could have no existence. But hitherto he has always taken a second place. He has been told to do this, that and the other thing, and he has gone and done it; but little deference has been paid to any of his rare expressions of opinion. He has been told that naval

matters are too hard for him, and that his true function consists in accomplishing the tasks set for him and asking no questions. He is shown, for example, a very limited space on certain plans, and told to put engines and boilers into it, which shall develop 10,000 horse power or some other trifle of that nature, but he is not allowed to suggest that if he had a freer hand he could produce a better speed result, let us say, for less power. He is told that a gun is to be worked in a particular way and that he must have the machinery for so working it, but he is not permitted to point out that the thing permits of being done in another way. He is not snubbed, exactly, but he has been taught to keep his own place and stand, hat in hand, when the naval architect, the artillerist and the sailor pass by.

"Considering how very important is the part played in a compulsory disjointed fashion by the Engineer, we venture to think that he has not been treated quite in the way that he deserves, and we go so far as to ask, is it not about time that the Engineer took the initiative and, reversing the normal practice, employed the Naval Architect and the Artillerist to carry out his designs? We hold that there can be but one sound answer to this question, and it may not be unprofitable to consider what way the Engineer would probably go to work.

"It goes without saying that he would come to the task of designing a fighting ship with a very fair knowledge of what has already been done, and with a mind quite free from prejudice. His first endeavor would be to produce an honest ship, a vessel quite free from shams of all kinds. He will be moderate in his promises, but then they will certainly be kept. As to the shape of the hull and the lines, these must be settled by the Naval Architect, acting under the general instructions of the Engineer.

"It would be clearly understood that the speed settled upon would be the true speed of the ship, and not a fancy result got on a four hours' run with picked coal and selected stokers.

"There would always be precisely similar vessels cruising in company. They would be as much alike as three Martini-Henry rifles. Every part of each would be interchangeable with any other of the three, and as the sea speeds of all would be the

same, there would be no waiting for the slowest, and they could always keep in company, save in the wildest weather.

"In one word, the Engineer's war ship would be less of a scientific museum and more of a floating gun carriage. Her claims would be modest, but what she promised to do she could do. The story told by past naval manœuvres goes to show that the promises of the modern war ship are seldom kept, and this simply because more is attempted than the wit of man can carry out."

When the Engineer's ship of war was finished, it was observed that she could be coaled quickly and steered more readily and reliably. She could steam faster for a protracted period because sufficient weight had been allowed to install reliable auxiliaries. Her bilges were accessible for cleaning. Considerable judgment had been exercised in providing for a system of ventilating the compartments. The fire main was a reliable one, and it was not impaired by numerous sharp angles and bends. The quarters of the officers were cut down, but the crew were more comfortable and contented.

In case it was found necessary to abandon the ship, there were enough boats to carry the entire ship's company, and these boats were of such a character that they could live in a sea way.

There was something else than an obsolete and ill-continued system of ladders and approaches to the hatches.

A simple and efficient way of battening down had been fitted.

The electric light plant was installed near the boilers and where it could receive the care and supervision of capable mechanics.

It was the production of a sea-going expert, not the creation of a theoretical scientist.

CONTRACT TRIAL OF THE MACHINERY OF THE *TEXAS*.

By Passed Assistant Engineer T. W. Kinkaid, U. S. Navy.

The second class battleship *Texas* was launched at the Norfolk Navy Yard June 28, 1892, her construction having been begun in June, 1889. The design was purchased by the Navy Department from the Barrow Ship Building Company, England. The machinery was built by the Richmond Locomotive and Machine Works of Richmond, Va., and dock trials to determine the acceptance of the machinery were held at the Norfolk Navy Yard on May 12th and 15th, 1894, as described in the Journal of August of the same year.

The ship having gone into commission on August 15th, 1895, the contractors for the machinery made preparation for a full power trial at sea, in order to determine the questions of final acceptance and premium. The contractors' force came on board September 6th, and did not quit the vessel until December 21st, their time having been well occupied, previous to the trial, in getting the bearings into shape and becoming acquainted with their respective duties. Several preliminary runs were made while the ship was at Hampton Roads, and these developed the fact that the main injection strainers were choked. The ship made the run from there to New York at a speed of about 90 revolutions per minute, and was docked at the navy yard, November 4th, 1895.

Structural weakness was very distinctly developed by the docking, the floors having buckled their brackets in numerous places and the cement near keel having been very generally cracked. Vertical clips of 4 by 4 inch angle iron were fitted to the floor brackets of the boiler compartments of the ship, and the cement was repaired. After several dock trials at the navy yard and a couple of runs out from Tompkinsville and back, the ship was

U. S. S. "TEXAS."

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ordered on her steam trial, and the latter took place on December 19th, 1895.

HULL.

The hull is of steel of domestic make.

The vertical keel weighs 20 pounds to the square foot. The flat keel plates have an inner thickness of 25 pounds per square foot fore and aft, outer thickness 18½ pounds per square foot within, and 16½ pounds beyond the limits of the double bottom. Remaining plating to under side of armor 18½ pounds per square foot within, and 16½ pounds beyond the limits of the double bottom.

The longitudinals within the double bottom are continuous throughout its length, and are formed of plates from 16 to 20 feet in length. The first, or shelf plate, is water tight, weighs 20 pounds per square foot; the second, water tight, 15 pounds; third, not water tight, 12.5 pounds; fourth, water tight, 15 pounds; fifth, not water tight, 12.5 pounds. Both the inner and outer angle bars on the longitudinals are continuous throughout their length in the double bottom.

The transverse frames are spaced 4 feet apart within the limits of the double bottom. Forward and abaft these limits the spacing is 3 feet. The water tight frames within the double bottom extend from the keel to the second longitudinal, and are formed of plating 12 pounds per square foot, with an angle bar 3 by 3 inches of 7 pounds per foot, worked between longitudinals. The other frames within the limits of the double bottom are formed, up to the second longitudinal, of bracket plates 10 pounds per square foot and short lengths of angle bar, 4½ by 3 inches of 9 pounds per foot for the outer bar, and 4½ by 3 inches of 8 pounds per foot for the inner bar. The angles connecting the brackets with the longitudinals are 3 by 3 inches of 6 pounds per foot, those connecting the brackets to the vertical keel being 3 by 3 inches of 7 pounds per foot. Above the second longitudinal, throughout the whole extent of the armor belt, the frames are formed of solid plates, 10 pounds per square foot with lightening holes. The outer angle bars are 3 by 3 inches of 7 pounds per foot, and the inner angle bars are 3 by 3 inches of 6 pounds per foot.

The frames under engine and boiler bearers are formed of solid plates, 12 pounds per square foot, lightened with holes, and double inner angles, 3 by 3 inches of 6 pounds per foot.

The double bottom compartments extend practically throughout the entire length of the ship and are terminated on each side by the armor shelves. Wing compartments extend for more than half the length of the ship and, in wake of the engine and fire rooms, where they permit access to the side armor, they are very large. The athwartship bulkheads cross the wings so as to give the necessary water tight subdivision. These wing compartments form a large, unoccupied space which might be adapted for use as coal bunkers. As at present arranged, they constitute a menace to the ship, as the flooding of a couple of them on one side would impart a serious list that would be very troublesome in action.

The side armor has a principal thickness of 12 inches, tapered to 7 inches at the bottom. It is of harveyized nickel steel, extending 3 feet above, and 4 feet below the water line, and protects the engine and boiler spaces for a length of 118 feet. The side armor is extended inboard diagonally at the ends to protect against a raking fire, the diagonal extensions being 17 feet in length and 8 inches in thickness. The protective deck is 2 inches thick on the flat and 3 inches thick on the slope. The thickness of the conning tower is 9 inches.

Battle hatches are fitted over each engine room, but they could not be closed in action without putting the engine room force *hors de combat* from asphyxia.

The armored redoubt extends diagonally across the ship, the turrets being mounted at the ends, the port turret forward. The redoubt armor is 12 inches thick and of nickel steel. The turrets are of 12-inch harveyized nickel steel. The central tubes carrying the hydraulic supply and exhaust pipes are of 6-inch steel, as are also the two rectangular ammunition tubes. The redoubt contains the hoisting and rammer gear, all operated by hydraulic power. There are two loading positions for each turret.

The piping to the hoisting and rammer gear is unprotected where it traverses the space between the protective deck and the

floor of the redoubt; which means that the main battery can be disabled by a lucky shot from a small gun.

ARMAMENT.

Each of the two turrets mounts a 12-inch rifle, which is run in and out, elevated and lowered by direct hydraulic pressure. The training is accomplished by rotating the turrets, which take their motion from a pinion driven by two sets of hydraulic engines of the Brotherhood type. The starting and reversing of the training engines are accomplished by manipulating a "change valve," a special design of Mr. Mellen, chief draftsman for the contractors. As will be seen from the illustrations of the turret turning machinery, the direction is reversed by simply interchanging the functions of the supply and exhaust pipes, the change valve being balanced under all conditions. The pinion shaft is extended overhead and carries a screw thread which, working in a nut on a float lever, checks the movement of the turret by shifting the lever of the change valve.

The other guns are six 6-inch, twelve 6-pounder R. F., six 1-pounders, four 37-mm. Hotchkiss revolving cannons and four 18-inch Whitehead torpedo tubes.

BUNKERS.

The bunkers are in upper and lower tiers in wake of engine and boiler spaces. They are convenient for supply to the fires, but can not be rapidly stowed. Their capacity is 877 tons.

DRAINAGE SYSTEM.

There are six main cisterns, one in the after end of each of the four boiler compartments, and one in the forward end of each engine compartment. The cistern in each engine compartment adjoins that in the boiler compartment just forward of it, and the two can be connected by a sluice valve operated from the gun deck. The four boiler compartments are connected by two fore-and-aft 12-inch pipes and by two athwartship pipes of the same size. The auxiliary drain is a 6-inch pipe running fore and aft on the port side of the keel.

The crankpits drain through branches into a 3-inch iron pipe which connects to engine room cistern. To pump out crank pits with the engine room bilge pumps, it is necessary to connect to auxiliary drain, drawing through manifold in after fire room, through main cistern of that fire room and through sluice valve connecting engine room and fire room cisterns.

HULL DATA.

Length between perpendiculars, feet	290
over all, feet and inches	308–10½
Beam, extreme, feet and inches	64–1
Midship section (immersed area) on trial, square feet	1,250
Draught at beginning of trial, forward, feet and inches	21–7
aft, feet and inches	23–11
end of trial, forward, feet and inches	21–3
aft, feet and inches	23–10
mean, for trial, feet and inches	22–7¼
Displacement at load draught, tons	6,300
mean draught on trial, tons	6,320
per inch immersion at L. W. L., tons	30.2
Weight of propelling machinery, tons	642 50
water in same, tons	150 21
stores, tools and appliances, tons	28.90
miscellaneous fittings, tons	50.19
Total machinery weights, tons	871.80

KIRK'S ANALYSIS.

Length Kirk's block model, feet	290
middle body, feet and inches	63–11.04
Mean draught, feet and inches	22–7¼
Beam, feet and inches	55–3.6
Area immersed midship section, square feet	1,250
Wetted surface, square feet	23,197
Calculated I.H.P. for mean speed of trial (17.8 knots), allowing 6 I.H.P. per 100 square feet wetted surface at 10 knots speed, power varying as cube of speed	7,849
Actual mean I.H P. (main engine, air, circulating and feed pumps, on trial)	8,506.560

TACTICAL DATA.

Tactical diameter, yards	540
Time for full circle, minutes and seconds	5–50
Speed, trial for tactical diameter, knots	11.5
Revolutions	80
Advance	None.

pipe
pits
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valve

00
8–10½"
4–1
0
1–7
3–11
1–3
3–10
2–7¼
300
320
30.2
642.50
150.21
28.90
50.19
871.80

-11.04
-7¼
-3.6

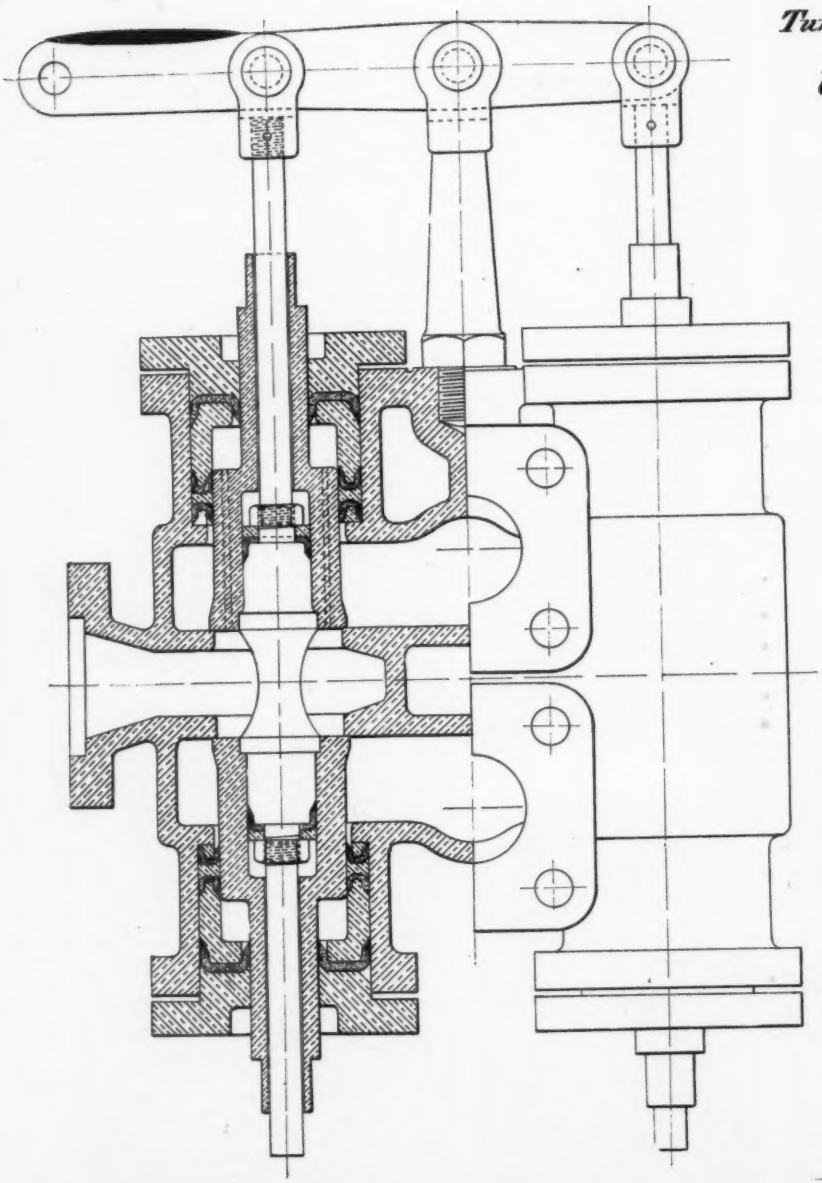
560

540
5–50
11.5
80
None.

REVI

Turre

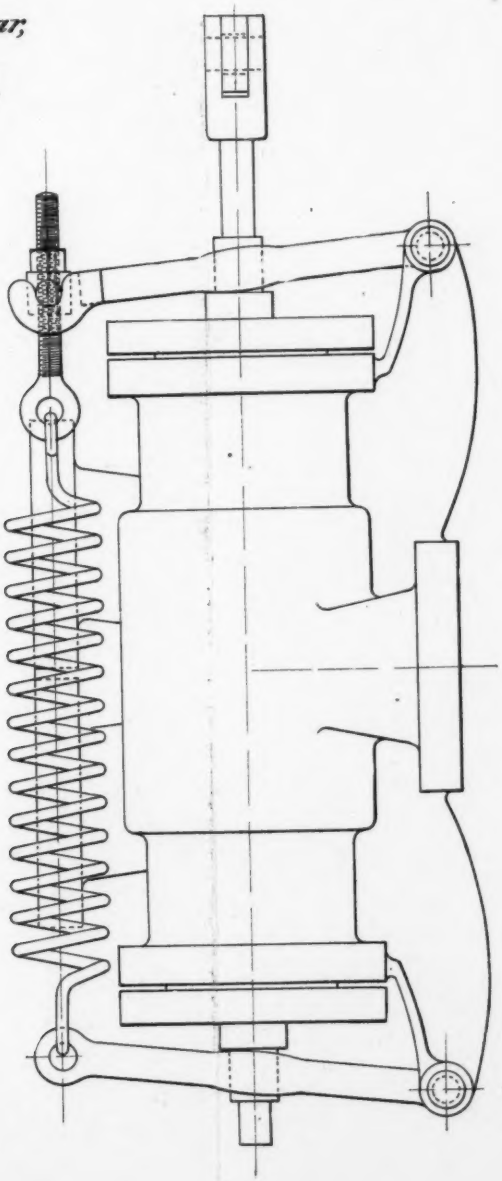
U.



VERSING GEAR.

ret Turning Gear,

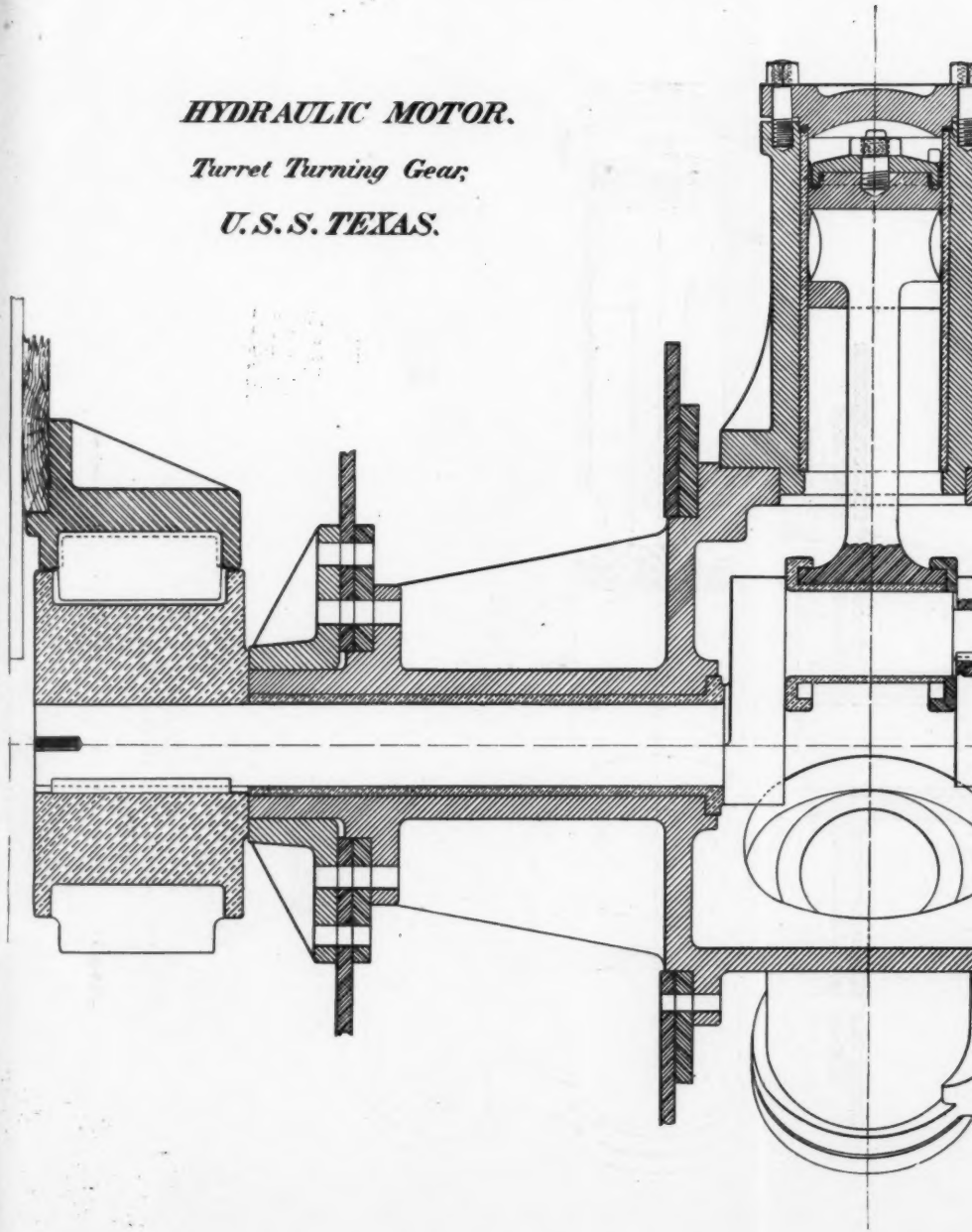
U. S. S. TEXAS.

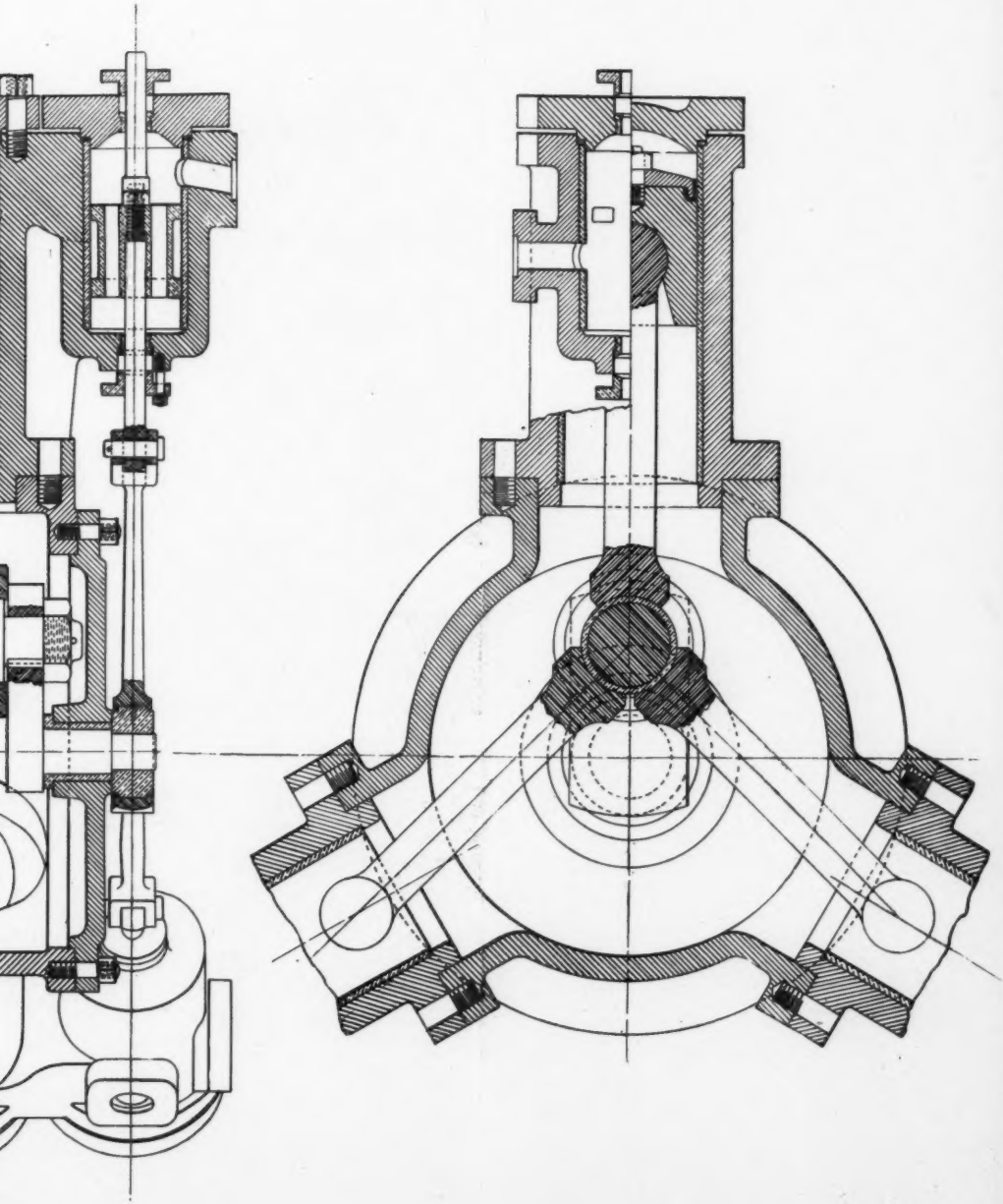


HYDRAULIC MOTOR.

Turret Turning Gear,

U.S.S. TEXAS.





MAIN ENGINES.

The main engines are of the vertical, inverted, direct acting, triple expansion type, with cylinders 36 inches, 51 inches and 78 inches in diameter by 39 inches stroke; the H.P. cylinder forward, L.P. cylinder aft. The jacketing is on top, sides and bottom. The six cast-steel supporting columns for each engine are of the inverted Y pattern. The crank pin brasses and main bearings are lined with an anti-friction metal prepared by the builders of the machinery. It is not inserted in strips, but has liberal oil grooves cut in. The metal appears to be too soft for continuous service. The eccentric straps are of cast steel, lined with composition. They have given considerable trouble from running warm. The eccentrics are of cast steel. The reversing gear is of the usual float lever type, with hydraulic controlling cylinder, operating on Stevenson double bar links. The cut off is adjusted by the usual sliding block working in a slot in the radius bar.

The H.P. and I.P. cylinders each have one double ported piston valve without packing rings, and the L.P. cylinder has a double ported slide valve with balance ring.

Each engine room contains one main condenser and one auxiliary condenser, the latter of Wheeler's make, with self-contained air and circulating pumps.

The main air pumps are compound and the pump cylinders are tandem with the steam cylinders. All the air pump cylinders are vertical and the frame bolts to engine room bulkhead. An overhead crankshaft carries Marshall valve gear. The cranks of these pumps are set at an angle of 135° with each other, the L.P. leading. A speed of about 175 revolutions is usually maintained in order to secure a vacuum, and at the same time minimize the risk of the pump stopping. The valves now in use are of soft vulcanized rubber, a single disc for each foot valve, bucket and delivery valve. The valves originally used were thin superimposed copper discs, each disc pierced with a number of small holes not coincident with those in the adjoining discs.

The circulating pumps are of the ordinary centrifugal type and deliver into the upper parts of the condensers, the outboard dis-

charges being below the turn of the bilge. The steam is on the outside of condenser tubes and the inflowing steam strikes the coldest tubes.

Each engine room is provided with an auxiliary fire and bilge pump and a fire and water service pump, each of the same size and pattern as the feed pumps. All pump rods and piston rods, including those of main engine, are packed with Katzenstein's metallic packing.

There is a double cylinder turning engine connected by worm gear to each crankshaft.

The contract provided for a premium of $100 for each I.H.P. above 8,600 and an equal penalty for falling below that power; the minimum power for acceptance to be 7,650.

Following are some of the principal dimensions and data concerning engine room machinery:

Cylinder diameters, inches	36, 51 and 78
Stroke, inches	39
Diameter piston rods, inches	7½
crankpins, inches (axial hole, 7 inches diameter)	14½
crankshaft, inches (axial hole, 6 inches diameter)	14
H.P. piston valve, inches	15
L.P. valve, inches	21
Extreme cut off	.71
Number of collars on one thrust shaft	7
Outside diameter collars, inches	23
Diameter thrust shaft, inches	13½
Inside diameter of main condenser, inches	69
Length of tubes inside tube sheets, inches	150
Number of ⅝-inch tubes, one condenser	3,087
Cooling surface, one condenser, outside tubes, square feet	6,316.4
Ratio total cooling surface to total heating surface	.3735
Cooling surface, one auxiliary condenser, square feet	260
Main air pump, H.P. cylinder diameter, inches	10
L.P. cylinder diameter, inches	18
plunger diameter, inches	15½
stroke, inches	15
Circulating pump, steam cylinder, diameter, inches	9
stroke, inches	8
diameter pipes and nozzles, inches	13
runner, inches	38
Capacity after trimming tank, fresh water, tons	34
Jacking engine, number of cylinders	2

Jacking engine, cylinder diameter, inches	4½
stroke, inches	6
number of revolutions to one of main engine	1,096
Time to jack main engine one turn, steam 100 pounds, minutes and seconds	2–36

BOILERS.

The boilers are four in number and are located in separate water tight compartments. Access to the boiler compartments is had through air locks in the central passage on platform deck. The after boiler rooms may also be entered through engine rooms, and the forward ones may be entered from dynamo rooms on the platform deck. There are eight fire room blowers, two to each boiler. They draw air from four trunks extending above the bridge deck alongside of uptakes and smoke stack. The boilers are double-ended, of open hearth steel, and have steel tubes. Each furnace has a separate back connection. There are no hydrokineters, the water being circulated, when getting up steam, by using auxiliary feed pumps. The principal boiler and blower dimensions are as follows:

Mean length, feet	18
diameter, feet	14
Working pressure, pounds	150
Thickness of shell plates, inches	1 5/32
tube sheets, inch	9/16
back sheet, back connection, inch	17/32
Number of furnaces, each boiler	6
Outside diameter of Fox furnaces, inches	43
Inside diameter of Fox furnaces, inches	39
Thickness of furnaces, inch	½
Grate surface, one boiler, square feet	132.9
Total grate surface, all boilers	531.6
Diameter of tubes, inches	2½
Length of tubes inside tube sheets, inches	81
Number of plain tubes, one boiler	642
stay tubes, one boiler	168
Heating surface, one boiler, square feet	4,228.1
all boilers, square feet	16,912.4
Ratio heating to grate surface	31.8
Diameter, main steam pipe, each boiler, inches	8½
main steam pipe at engine, inches	11½
Ratio tube area to grate surface	.208

Height, top of smoke pipe above lowest grate, feet	70
Weight of one boiler without water, tons	52.76
water in one boiler, steaming level, tons	34.183

BLOWERS.

Fire room blowers, diameter and stroke, inches	7 by 4½
of fan, inches	69
Engine room exhaust fans, diameter and stroke, inches	6 by 4
of fan, inches	54
Dynamo room blower, diameter and stroke, inches	3¾ by 2½
Two berth deck blowers, diameter and stroke, inches	4¼ by 3
of fan, inches	65

FEED SYSTEM.

Each engine room contains a feed tank, 5 feet 10 inches by 4 feet 6 inches by 2 feet 8 inches. From each tank two suction pipes lead forward, one for the main feed pumps, the other for the auxiliary pumps. Each boiler room has a main feed pump, which is connected to feed only its own boiler from the main feed tank. There is also in each boiler room an auxiliary pump, which can feed its own boiler from the tank and the sea, and can be used for fire and bilge purposes. But neither of the feed pumps in any boiler room can feed or pump from any but its own boiler. Branches from the forward auxiliary feed pipes replenish the hydraulic tanks. The main and auxiliary feed pumps are alike. They are double cylinder tandem pumps.

Diameter steam cylinders, inches	7
water cylinder, inches	4½
Stroke, inches	9

TRAPS.

Steam traps of the Curtis patent are liberally used on the main and auxiliary steam pipes and for the heating systems. These traps, together with all cylinder and steam chest drains of auxiliary machinery, drain into a 1½-inch main drain pipe running fore and aft on each side of the center line of the ship, with branches to deliver into auxiliary condenser, main air pump channel, or into bilge, as desired. The water from cylinder

jackets is also trapped and sent into feed tank or air pump channel.

EVAPORATORS AND DISTILLERS.

There are two Baird evaporators, No. 3, upright. The distillers are also Baird's.

DYNAMOS AND STEERING ENGINE.

The dynamos are two in number, of the Edison 4 pole marine type, with two steam cylinders to each, 12½ inches in diameter, and a stroke of 6 inches.

The steam steering engine is of the Williamson type, with a steam cylinder 13 inches in diameter and a stroke of 10 inches.

HYDRAULIC PLANT.

The hydraulic plant consists of four Davidson double plunger pumps, steam cylinders 24 inches diameter by 12 inches stroke, the rams being 6¼ inches diameter; two Westinghouse 8-inch air pumps with air cylinders bushed down to 5 inches diameter; two hydraulic air compressors, taking air from Westinghouse pump at 250 pounds and compressing to 1,000 pounds or more as desired for cushioning the two accumulators; four air flasks connected to accumulators. The plant is located in two water tight compartments immediately forward of the forward fire rooms. The ventilation of the hydraulic rooms is inadequate and the pump attendants suffer severely from heat and foul air. The hydraulic pressure ordinarily used at gun drill is from 1,200 to 1,500 pounds. The hydraulic mains are of 4-inch copper pipe with composition fittings and leather packing. A considerable length of the piping is situated in the upper parts of the fire rooms, where the intense heat soon destroys the leather packing. The capacity of the two hydraulic tanks is 2,400 gallons.

THE TRIAL.

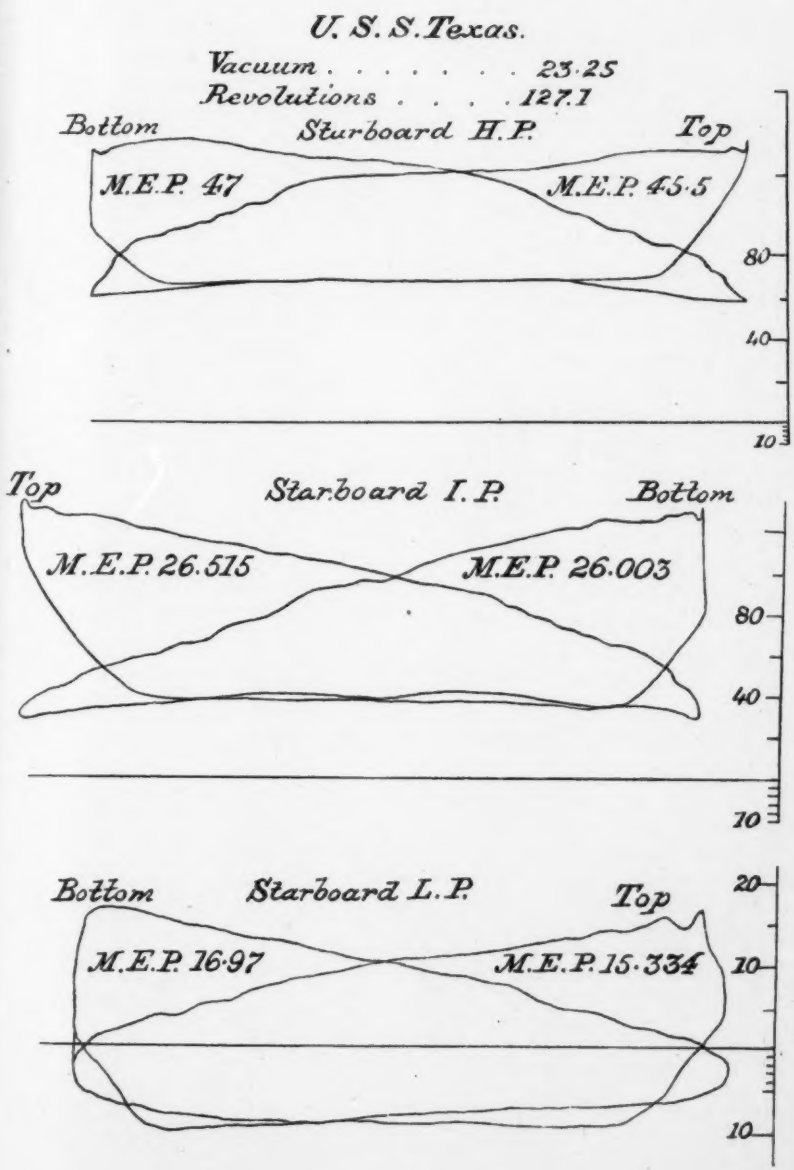
The trial commenced off Sandy Hook at 10·30 A. M., December 19th, in calm weather. The cut offs of starboard engine were not touched; those of port H.P. engine being shortened up occasionally, but soon afterward let out to full throw.

Previous examinations had shown that the dry pipes in port boilers were not so carefully fitted as those on starboard side. At 2·04 P. M., port L.P. cylinder commenced thumping so badly, due to priming, that it would have been impossible to continue at full speed, even if other causes had not operated to stop the trial. The priming occurred just after an increase of speed following an accident to starboard circulating pump, which caused starboard engine to be stopped. The trial seemed to be progressing satisfactorily until about 12·20, when the water accumulated to such an extent in both H.P. crank pits that the taking of data was almost impossible. At 1·36 P. M., a hot crank pin caused the starboard circulating pump to be shut down and the starboard main engines were, in consequence, stopped. The disabled pump had been deluged with bilge water for nearly an hour, and it was also discovered that the key of balance wheel had worked slack. At 1·50 P. M., the starboard engine was started up and trial continued, but at 2·06 it became necessary to slow down on account of the water flying from crank pits, and at 2·10 the trial was declared off.

During the trial it was noticed that one of the middle furnaces of starboard forward boiler did not draw well, and that but little coal was consumed by it. This was due to leaks in the back connection, which caused the tube sheet to become choked with wet ashes.

The data of the trial give the following results:

	Starboard.	*Port.*
Steam pressure in boilers, mean, pounds per square inch, by gauge	151.9	151.5
Steam pressure at engines, mean	140.8	141.1
Steam pressure, first receiver, above a perfect vacuum	77·	72.7
Steam pressure, second receiver, above a perfect vacuum	30.7	33.1
Revolutions per minute, mean	125.9	124.6
Mean effective pressure, H.P. cylinder, average, pounds per square inch	45.400	44.863
Mean effective pressure, I.P. cylinder, average, pounds per square inch	25.355	25.932


U. S. S. Texas.
Vacuum . . . . . 23·25
Revolutions 127.1
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Starboard H.P.
Top
M.E.P. 47
M.E.P. 45·5
80
40
10
Top
Starboard I.P.
Bottom
M.E.P. 26.515
M.E.P. 26.003
80
40
10
Bottom
Starboard L.P.
Top
M.E.P. 16·97
M.E.P. 15·334
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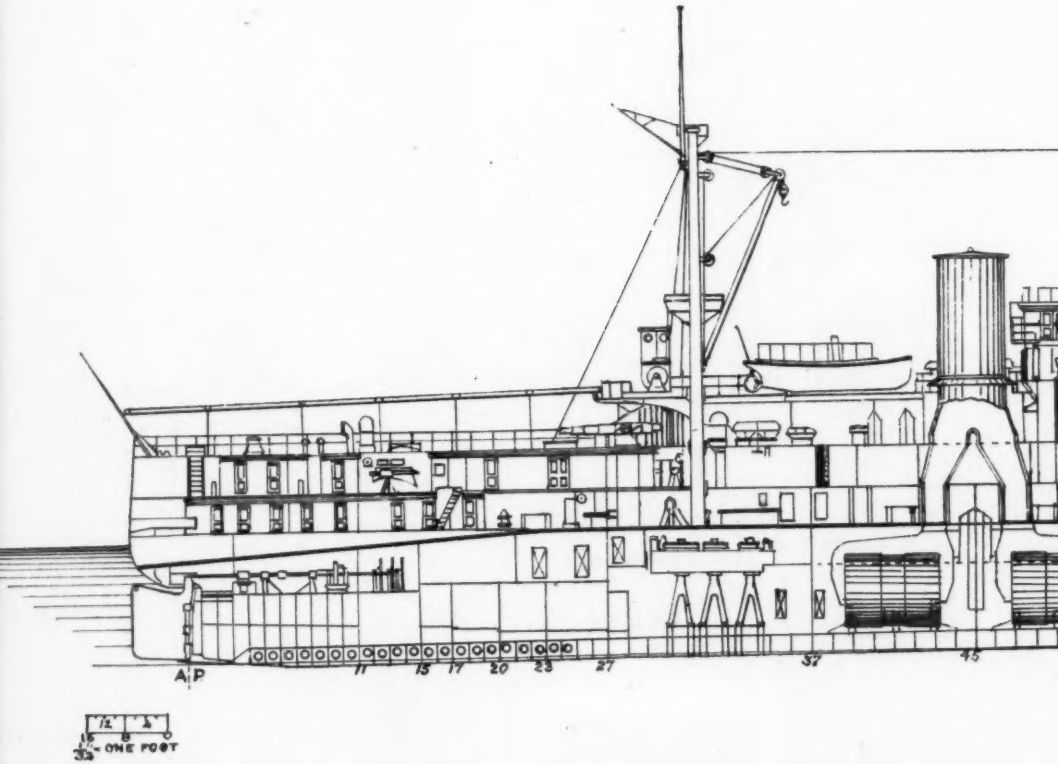
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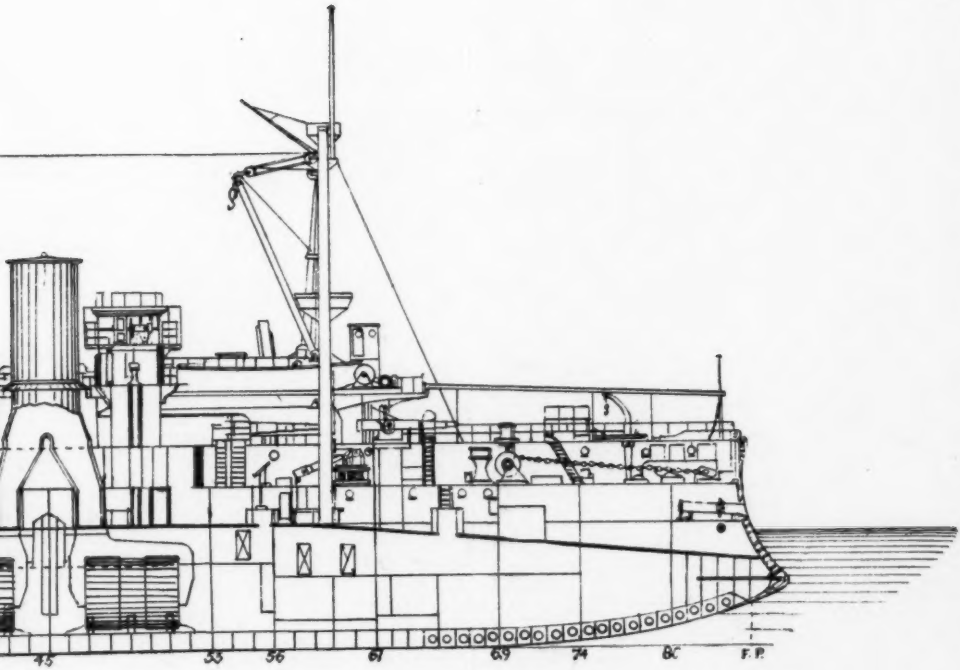
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74
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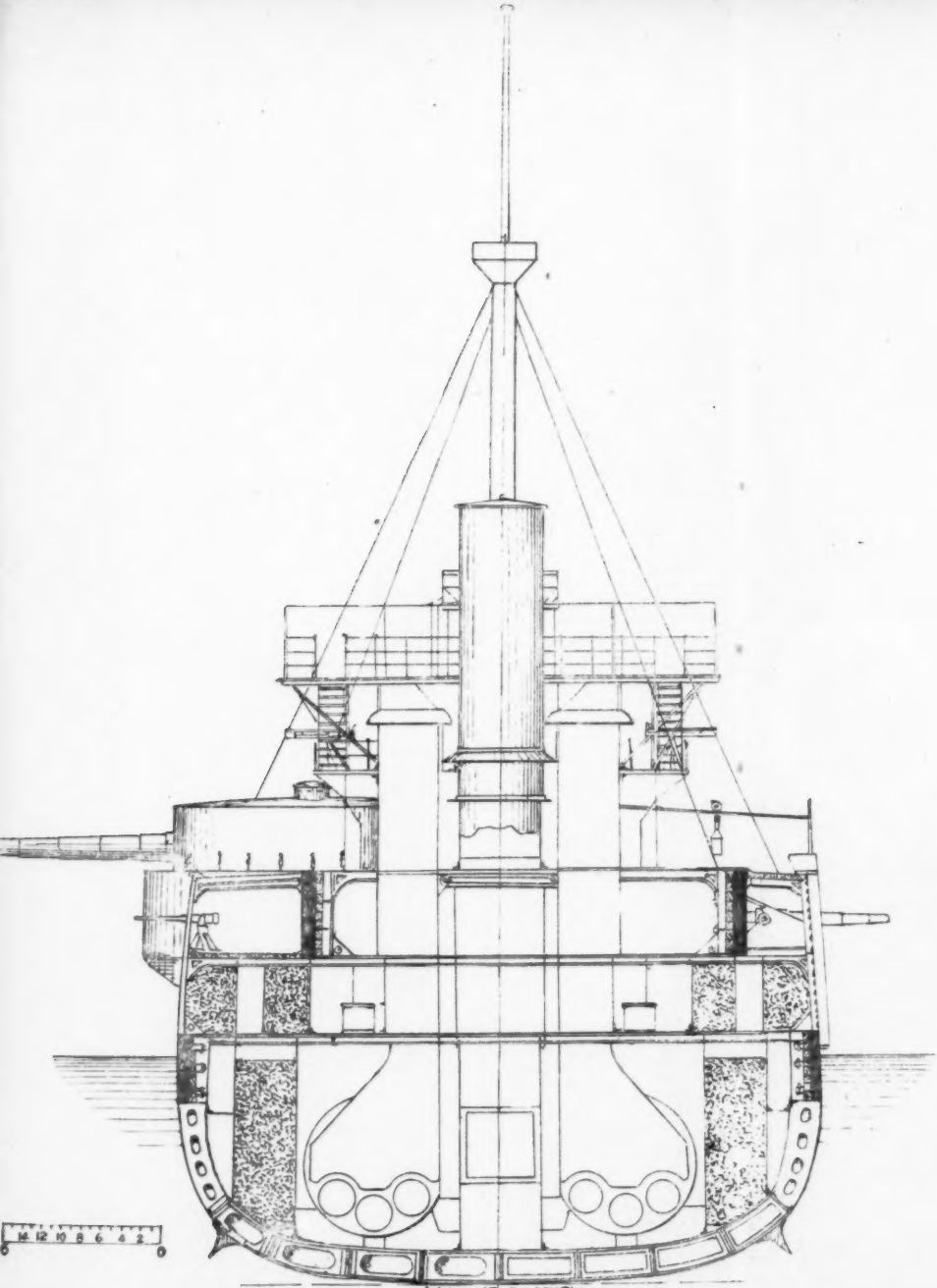
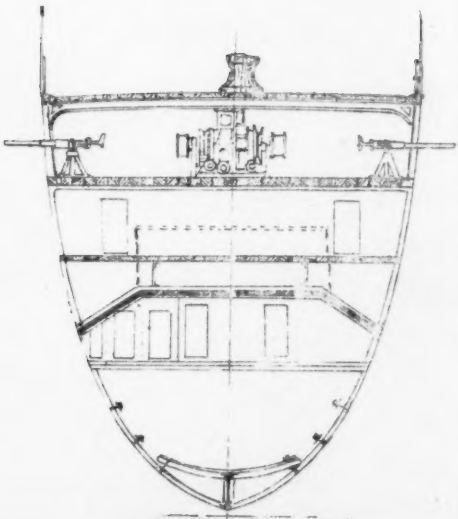
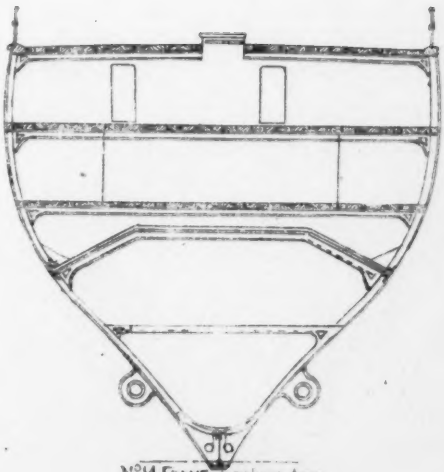
F.P.



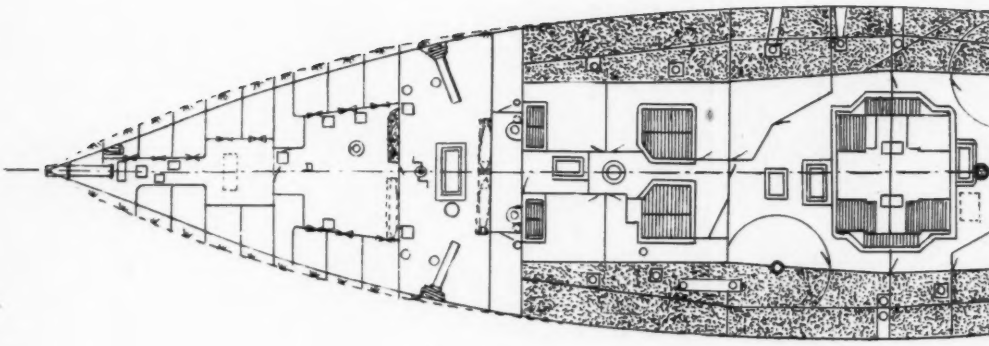
MIDSHIP SECTION

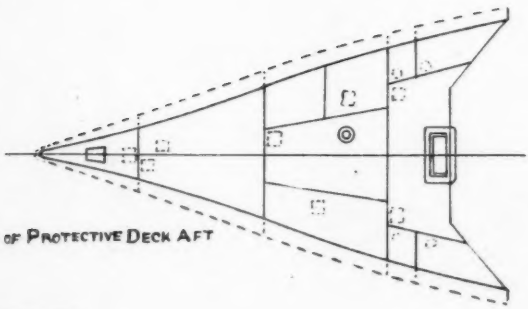


No 69 Frame Looking For?

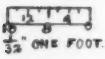


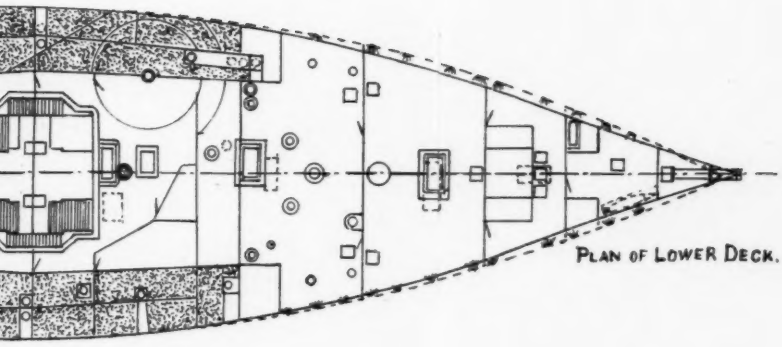
No 14 Frame Looking Aft



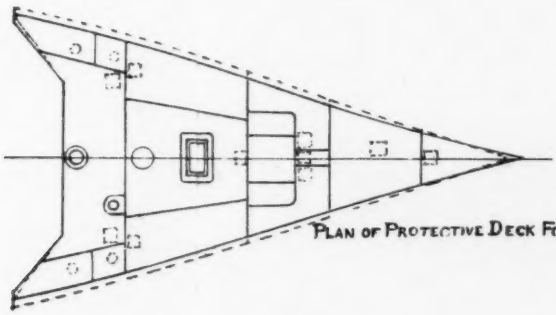


PLAN OF PROTECTIVE DECK AFT

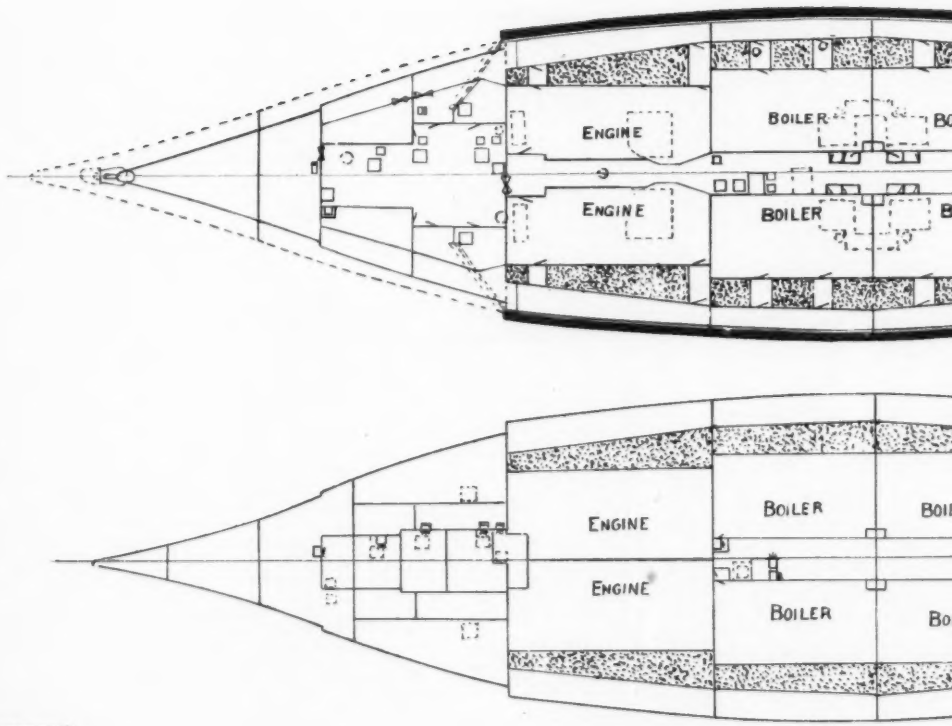




PLAN OF LOWER DECK.

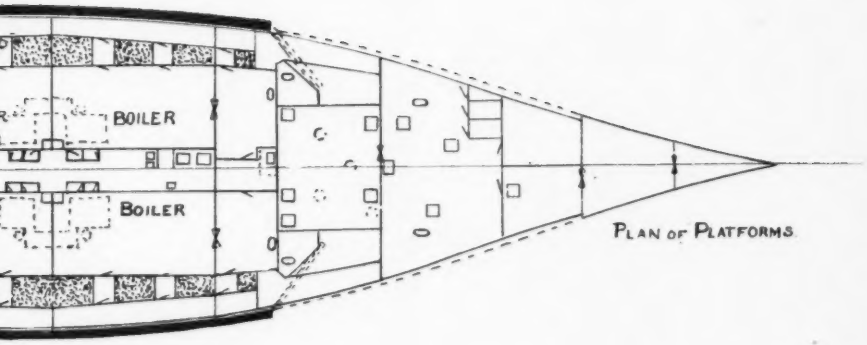


PLAN OF PROTECTIVE DECK FORWARD.

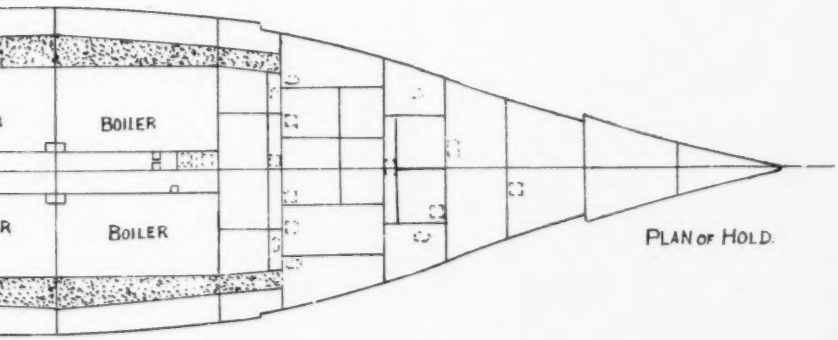


16 8 0

$\frac{1}{32}$" = ONE FOOT



PLAN OF PLATFORMS.



PLAN OF HOLD.

	Starboard.		*Port.*
Mean effective pressure, L.P. cylinder, average, pounds per square inch	15.648		15.212
Ratio L.P. to H.P. cylinder		4.694	
I.P. to H.P. cylinder		2.007	
L.P. to I.P. cylinder		2.339	
Average mean effective pressure on L.P. piston equivalent to aggregate mean effective pressure on all pistons	36.159		35.855
Temperature in fire rooms, degrees Fahrenheit		108.4	
engine rooms (at working gear), degrees Fahrenheit		93.2	
Temperature of injection water, degrees Fahrenheit		51.5	
Temperature of discharge water, degrees Fahrenheit		90.6	
Temperature of air pump discharge, degrees Fahrenheit		119.6	
Temperature of feed tank, degrees Fahrenheit		130.3	
Revolutions per minute, air pumps		192.9	
circulating pumps		180	
fire room blowers		437	
feed pumps		47.2	
Air pressure, inches of water		1.776	

INDICATED HORSE POWER.

	Starboard.		*Port.*
Main engines, H.P. cylinder	1,119.762		1,107.902
I.P. "	1,269.370		1,299.218
L.P. "	1,833.201		1,793.274
total	4,222.333		4,200.394
Total		8,422 727	
Air pump	12.369		9.761
Circulating pump	31.48		19.241
Total, air and circulating pumps		72.851	
Feed pumps		10.982	
Collective I.H.P., main engines, air, circulating and feed pumps		8,506.560	
Collective I.H.P., main and all auxiliary engines in operation during the trial		8,610.0915	
Collective, all machinery, during trial, per square foot of grate surface		16.197	
Same, per square foot heating surface		.5091	
Collective, main engines, air, circulating and feed pumps per square foot of grate surface		16.001	
Same, per square foot of heating surface		.5029	

Coal, per hour, pounds	17,042.4
per I.H.P. (main engines, air, feed and circulating pumps)	2.003
Same (all machinery in operation)	1.979
Coal, per square foot grate surface, per hour, pounds	32.6
Coal, per square foot, heating surface, pounds	1.008
Cooling surface, square foot, per I.H.P.	.7638
Heating surface, square feet, per I.H.P.	1.964
$Speed^3 \times$ immersed midship section $\div$ I.H.P.	871.29
$Speed^3 \times displacement^{2/3} \div$ I.H.P.	228.24

The coal used was Pocahontas, hand picked, put up in 200-pound bags, except a little Cumberland coal that was used when the Pocahontas coal could not be reached.

TEST OF A No. 4, TYPE B, (HORIZONTAL) EVAPORATOR.

By Chief Engineer G. W. Baird, U. S. Navy.

This machine is for the *Nashville*, formerly Gunboat No. 7. It is cylindrical in form, but with hemispherical ends. It has return U tubes, expanded into a cast-iron tube sheet. The water condensed in the tubes empties into a pocket and makes a second (return) circuit along the bottom of the machine, it being then sufficiently cooled to be worked by the pumps. The tubes were tested at 250 pounds and the shell at 100 pounds per square inch internal pressure. The surface of evaporation and the volume of steam room were, relatively, larger than any machine I had previously designed. The shell is of plate-steel, the tubes of charcoal-iron, the steam chest of cast-iron and the gauges and fittings of brass. The principal dimensions are as follows:

Diameter of shell, inches	52
Length of shell, inches	60
and steam chest, inches	66
Number of return tubes	30
Diameter of tubes, inches	1½
Thickness of tubes, number of B. W. G.	14
Total heating surface, square feet	134
Weight, cast iron, pounds	600
tubes	425
fittings	55
wought iron	1,232
covering	160
steam trap	150
Total weight	2,622

MANNER OF MAKING THE TEST.

The live steam was drawn from the shop boiler which was, unfortunately, so far away that the drop was very great. The

boiler was not large enough to supply the machine for an extended period. The feed water was drawn from the hydrant, and measured by an Empire meter which had been previously tested and found correct. The height of water in the gauge glass was kept constant.

The following give the observed data and results of the test:

Duration of test, minutes	36
Mean pressure in coils, above atmosphere, pounds	35
shell, above atmosphere, pounds	24
temperature of the feed water, degrees	70
Total pounds of water vaporized	1,308.5
Pounds of water vaporized per hour	2,180.5
Mean number of gallons vaporized per 24 hours	6,977
hour per square foot of surface	2.17
Heat units accounted for, per hour, in the water vaporized	2,369,954.
Pounds of water vaporized per hour per square foot of heating surface	16.25
Thermal units transmitted per hour per square foot of heating surface	17,686.
Thermal units transmitted per hour per square foot of heating surface per degree difference of temperature	19.6

Tests of No. 3B machines were made during the working hours of the shop, when the boilers could afford still less steam. The mean pressure in the coils was but 28.25 pounds; in the shell 7.15 pounds; and the water vaporized per hour, 915.6 pounds, or 2,930 gallons per day. They stood the same test pressures as the No. 4. These two are for the *Wilmington* and *Helena*, formerly gunboats Nos. 8 and 9. In testing the No. 3 machines, it was found, at first, that they were running below the rated output, and previous experience led at once to an examination of the trap, which was found "air bound." The steam trap filling with air is a fruitful source of trouble in an evaporating plant. Machines have so often been under rated in consequence of the trap becoming "air bound," or, in many cases having traps too small. My first evaporator was built in 1882, for the *Lookout;* it was intended to be mounted on and to drain directly back into the boiler. On testing it, I found it was not satisfactory. To my friend Herman Winter I am indebted for the suggestion that it probably filled with air. I then placed an intermediate chamber in it, with one

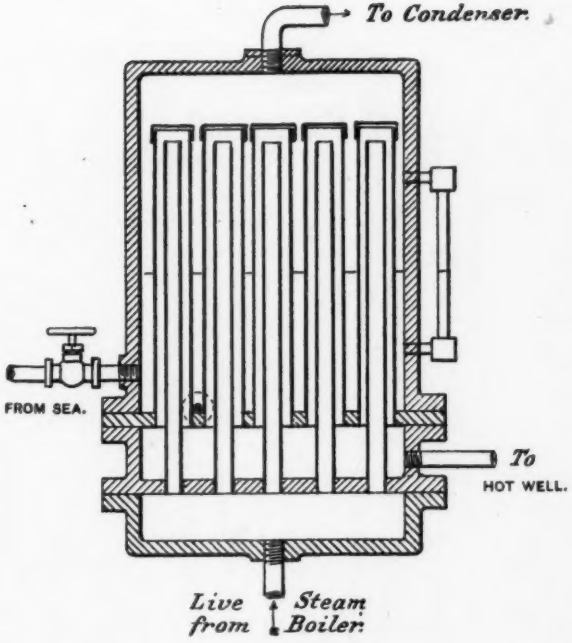


FIGURE 1.

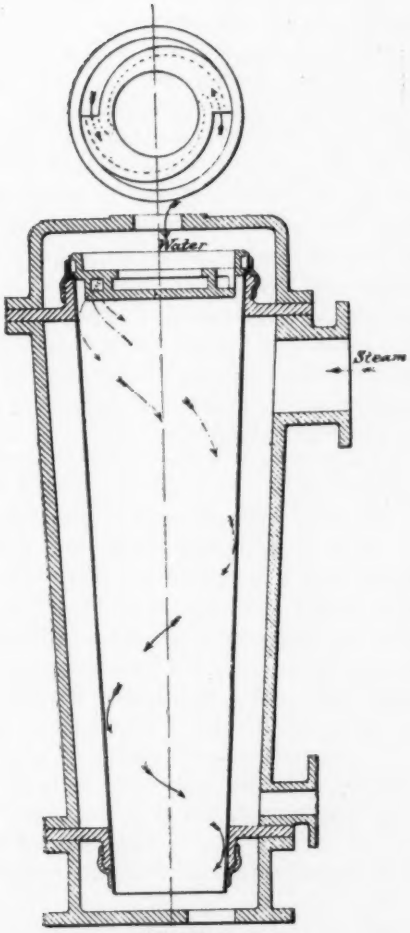


FIGURE 2.

tube inside the other, (see Fig. 1,) to force a circulation, and connected the drain to a steam trap, after which the machine worked. This machine was built by Sommerville & Sons, Washington, D. C. This type of machine, which requires two tubes to produce the heating surface of one, was objectionable on account of weight; and the many screw joints on the tubes, which, offering just so many opportunities for leaks, were also objectionable.

In 1871, I made a test on a small condenser, (Fig. 2,) built by the late David Stoddart, of San Francisco. It was the invention of the late Norman W. Wheeler. The tube, 7 inches in diameter at the top and 5 inches at the bottom and 21 inches long, exposed a surface of 2.85 square feet. This machine condensed, on each square foot of exposed surface, two pounds of water per minute, or twice the amount that other condensers had reached. The quantity of injection water used, although much less than that required in other condensers, was discharged from the condenser so hot that considerable vapor came from it. This showed that the thermal units of the condensed and condensing water did not balance, and it was evident that the water condensed on the outside of the tube drew upon the latent as well as the sensible heat of the refrigerating water. The refrigerating water was projected spirally in a thin film into the tube, Fig. 2. It was then my purpose to condense and utilize the steam formed inside the tube, by connecting both sides of the tube to the air pump, utilizing the water thus collected as a "make-up" for the fresh feed supply. This was, I believe, the first attempt at an "evaporator." My efforts, however, in this first attempt, were not successful, for three reasons:

I. The arrangement of combining the main condenser of a ship and the evaporator, would require the condenser to be run so hot as to diminish the vacuum.

II. The formation of scale in the condenser tubes was opposed by engineers.

III. The engineering world had not reached the era when the need of an evaporator could be made apparent to them.

THE RELIABILITY OF "THROTTLING CALORIMETERS."

By Jas. E. Denton, Hoboken, N. J.

[Read at the New York meeting of the American Society of Mechanical Engineers, December, 1895.]

The object of this paper is to present the complete * results of an investigation of this subject, undertaken at the request of a leading firm of builders of boilers † to determine:

First. Whether it is, or is not, true that the proportion of moisture in steam as determined by the accepted methods of using a "throttling calorimeter" may be considerably in excess of the true proportion of such moisture.

Second. The conditions under which "throttling calorimeters" should be used, or the precautions necessary in using them, in order to insure practically accurate conclusions regarding the proportion of moisture in the steam under examination.

The investigation has divided itself into the following parts:

I.

The entire output of steam from a seventy-five horse power boiler was made to contain known amounts of moisture while flowing through a three-inch pipe, the determination of the true percentage of moisture being made to depend entirely on actual weighings of the steam and water involved. (See Fig. 1.)

The outlet from the three-inch pipe was connected with a seventy-five horse power separator, and with a large throttling chamber, so that the principle of the small "throttling calorimeters with separator attached," could be applied to the *entire*

* The experimental data covering parts of the investigation have been presented to the Society, in two papers, by Prof. D. S. Jacobus; vol. xvi., pages 448, 1017 (abstract of first paper reprinted in Journal on page 140, vol. vii).

† The Babcock and Wilcox Co. of New York.

amount of steam mixture flowing through the pipe. Thereby it was determined that the *principle* of the "throttling calorimeter" was entirely reliable as a means of determining the percentage of moisture of any mixture which *passed through it.* (See Table A.)

II.*

Small "throttling calorimeters" were applied to the three-inch pipe, with the ordinary arrangement of perforated nipple, and it was found that the percentage of moisture shown by them varied considerably from the true percentage, when the conditions were such as to make it probable that the moisture was separated from the steam or was not distributed throughout the latter, when it collided with the nipple of the calorimeter. For instance, when the true moisture was 21 per cent. and 17.6 per cent. respectively, the small calorimeter showed 54.6 per cent. and 50.8 per cent.

III.*

Small calorimeters were applied to the three-inch pipe at the exit from the seventy-five horse power separator, with the drip pipe to the separator closed, under conditions which fairly insured the thorough distribution of the moisture throughout the current of steam when the latter collided with the calorimeter nipple, and it was found that, while the percentage of moisture shown by them was still liable to exceed the true percentage, the discrepancy was much less than when the conditions were such as to favor the accumulation of the moisture at some part of the surface of the pipe. For instance, when the true moisture was 0.5 per cent., 0.8 per cent., 1 per cent., 1.6 per cent., 2.5 per cent. and 19.1 per cent., respectively, the calorimeter showed 1 per cent., 1.5 per cent., 2.2 per cent., 3.6 per cent., 5.5 per cent. and 31.8 per cent. (See Table B.)

CONCLUSIONS FROM I, II AND III.

The results of I, II and III made it evident that, while the small "throttling calorimeter" might be relied upon to determine

* See paper by Prof. D. S. Jacobus. "Transactions American Society of Mechanical Engineers," vol. xvi, page 448.

correctly the amount of moisture in the sample of steam and water which is drawn into the instrument from the larger volume of mixture in a steam main, the percentage of moisture in such a sample may largely exceed the percentage in the steam main, if the moisture in the latter separates itself from the steam so as to accumulate at the point of connection of the calorimeter. It became necessary, therefore, to determine whether, under the usual conditions of good boiler practice—that is, for conditions where the moisture does not exceed 1½ per cent.—there can be such a separation of the moisture from the steam so as to cause the erratic indication of the calorimeter.

IV.

To investigate this question two sets of experiments were made, namely:

(*a*) Two small Barrus calorimeters (see Appendix) were arranged with an open ended nipple working through a stuffing-box by means of a screw, so that the end of the nipple could be moved radially in a steam main. One calorimeter was attached to the 12-inch horizontal main of a 500-horse power boiler, at its bottom, and the other at about four inches along the circumference away from the bottom point. By one of the screws controlling the nipples, the inner open end of the latter could be located anywhere in the pipe, from flush with its inside surface to seven inches beyond the latter. When the boiler was known, by means of the absence of drip from a separator, beyond the calorimeters, to be generating dry steam, the bottom calorimeter showed dry steam when the end of its nipple was more than one and three-quarters inches away from the side of the pipe, and from 35 per cent. to 47 per cent. of moisture when it was at less than this distance away; while the other calorimeter showed no moisture at all possible positions of its nipple. (See Table Part IV a.) The actual weight of water which passed through the calorimeter when it indicated 47 per cent. of moisture, represented only about one-third per cent. of moisture in the output of the boiler. The results, therefore, confirmed the hypothesis

that less than one-half per cent. of moisture in a steam main might separate itself from the steam, and accumulate at the bottom of a pipe in a stream which would impinge against a calorimeter nipple in its path so as to flow up the side and into the orifice of the latter, thereby causing the indications of the instrument to greatly exaggerate the true percentage of moisture in the main. Evidently, if this hypothesis were correct, the extent to which moisture could separate itself between the outlet for steam from a boiler to the point where a calorimeter was attached would depend upon the velocity in the steam main, the diameter of the latter, and the distance from the boiler outlet to the calorimeter. In other words, the moisture, in dropping out of the steam in a horizontal pipe, would probably roughly follow the law of a falling body, and to ascertain how far this was the case we undertook experiment

(*b*) The same apparatus was used as described above in connection with I, II and III, except that the 75-horse power separator was omitted * (see plate C), and the small "throttling calorimeter" was connected with an open nipple, whose inner end was flush with the inside of the three-inch pipe. The moisture was created in the steam by circulating cold water through a pipe located within the three-inch steam main. After passing the small calorimeter the steam was throttled in the drum N, and from the indications of the latter, and those of the small calorimeter, the per cent. of the total moisture in the three inch main was accurately determined. The amounts of moisture created in the three-inch main were confined to from one-half to ten per cent., and the velocity of flow was varied from 15 to 65 feet per second by varying the rate of steam generated by the boiler from 20 to 90-horse power.

The results (Table C) clearly indicate that, in traveling a little more than twice the distance in the three-inch main—which would be necessary in order for a body to fall by gravity through the diameter of the pipe—*practically all* of the moisture in the steam main would escape through the calorimeter.

* See paper DCLII, by Professor D. S. Jacobus. "Transactions American Society of Mechanical Engineers," Volume xvi, p. 1017.

Conclusions.

These results afford, I think, a key for the explanation of the erratic indications of "throttling calorimeters" in practice, which all extensive users of them have met to a greater or less extent. Variations in the proportions and arrangement of nipples, in the rate of evaporation, relative location of calorimeter, and position of steam mains leading to the point of attachment of the latter, will give rise to an infinite variety of results in the degree of the error which may be involved in the use of the instrument.

All parts of the surface of any form of nozzle inserted in the steam main will act as a collector for moisture, which will adhere to the metal so as to resist being detached by the comparatively swift main current of steam, but which will allow itself to be gradually drawn into the nozzle by the gentler current of steam which flows into the calorimeter, because the latter has only to overcome the resistance to sliding of the water along the metal.

Under this view there seems to be no possible method of depending solely upon small "throttling calorimeters" to determine with certainty the percentage of moisture in a steam main. By using several instruments simultaneously, with the orifices of the nipples located at different parts of the cross-section of the main, or by making the nipple of a single instrument movable so as to explore the interior of the pipe—an approximately correct judgment may be made regarding the average moisture, which will be sufficiently complete for commercial purposes.

By combining a single calorimeter with a separator acting on the whole current in the steam main, however, the source of error in the calorimeter may be so far eliminated as to make its indications reliable. This method is based upon the fact that, by using a separator of sufficiently large proportions to confine the velocity of flow within certain limits, the moisture in the steam leaving the separator can be reduced from any probable amount to a small fraction of one per cent. For example, in the case of the three-inch Stratton separator, if the velocity of flow is not more than one thousand feet per minute, with 27 per cent. of moisture in the steam entering the separator, there is practically no moist-

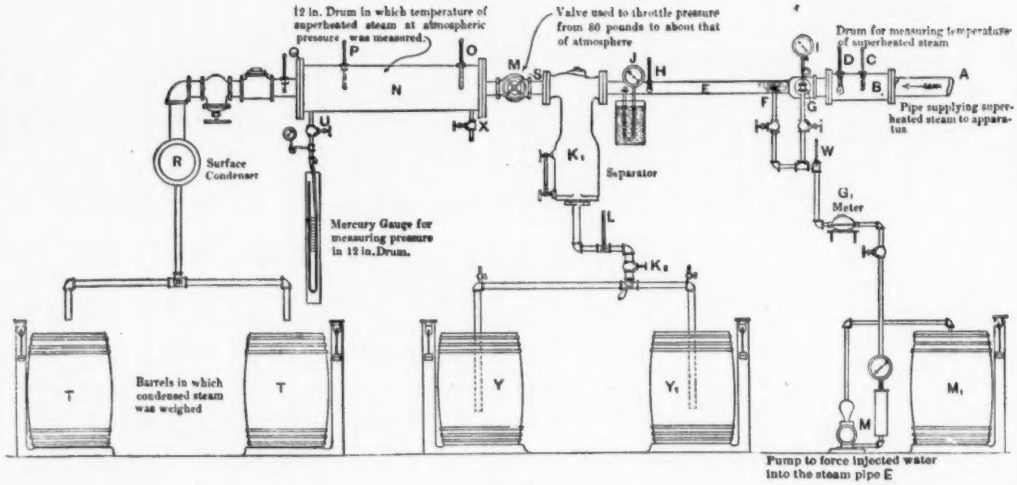

12 in. Drum in which temperature of superheated steam at atmospheric pressure was measured.
Valve used to throttle pressure from 80 pounds to about that of atmosphere
Drum for measuring temperature of superheated steam
Pipe supplying superheated steam to apparatus
Surface Condenser
Mercury Gauge for measuring pressure in 12 in. Drum.
Separator
Meter
Barrels in which condensed steam was weighed
Pump to force injected water into the steam pipe E

FIG. 1.

ure in the steam which leaves it. If, therefore, a small "throttling calorimeter" be applied to the steam main at the exit from such a separator, the small amount of moisture there, and the fact that it will be thoroughly intermingled with the steam, make it reasonably certain that its indications will be correct for any arrangement of nipple, and, by combining these with the determinations of drip from the separator, the moisture in the steam generated by the boiler may be completely and reliably determined.

APPENDIX.

GENERAL ARRANGEMENT OF APPARATUS FOR EXPERIMENT.

The principal arrangements for the investigation are shown by Fig. 1.

Steam was drawn from boilers by a three-inch pipe A. The latter was enlarged to six inches at B, whereby the velocity of the flow of steam was made sufficiently low to enable its temperature to be accurately determined by means of the thermometers C and D. As the steam flowed past the points G and F, a stream of water was injected into it by means of the pump W, from a reservoir W_1, the rate of injection being regulated by means of the water meter G_1. When the water was injected at G it issued against the steam in an unbroken stream through small orifices; but when it was injected at F, two streams of water, at an angle, were made to impinge against each other so as to spatter into a fine spray.*

The mixture of steam and water then passed a three-inch Stratton separator K. The water was withdrawn from the latter by the valve K_2, whence it passed into the weighing barrels Y and Y_1, the level in the water glass K_1 being maintained at about one inch above its lower end.

The steam leaving the separator passed through the globe valve M into a drum N, twelve inches in diameter and about five feet long, the valve M being regulated so that while at J the desired

* It was thought that the injection of the water as spray would be necessary to enable it to have acquired the temperature of the steam before it left the separator, but it was found that both methods of injection were equally effective in this respect.

boiler pressure was maintained, the pressure in N, as shown by pressure gauge U, would not be more than a fraction of a pound above that of the atmosphere. The temperature of the steam being given by the thermometers O, P and Q, this drum constituted a "throttling calorimeter" adapted to receive the whole amount of steam operated upon.

The small calorimeters to be tested were applied at S and H, the separating attachment and throttling device being both used for these two positions. The throttling device was also used alone at position S.

From N the steam flowed to a surface condenser R, in which it was condensed so as to be weighed in the barrels T and T_1.

All parts of the apparatus were well insulated with canvas-covered hair felt.

Part I.

EXPERIMENTS PROVING RELIABILITY OF PRINCIPLE OF "THROTTLING CALORIMETER."

With the small calorimeters disconnected so that all of the steam from the boiler flows to the Stratton separator, the latter separator combined with the throttling drum N represents a "throttling calorimeter," with separator attachment, which operates upon the whole current of steam under examination.

The total weight of mixed steam and water entering the separator is the sum of the weights collected in Y and Y_1, T and T_1. If the steam at B is slightly superheated, its condition as received from the boiler is determined by the thermometers C or D. Then, knowing the weight of water injected from W_1, and that the latter is heated to the temperature corresponding to the pressure of the steam at J, by means of the thermometers H and L, the percentage of moisture in the separator is determinable. Therefore, the proportion of this moisture eliminated by the separator, or the percentage of the moisture in the steam leaving the latter, is determinable from the amount of water collected in Y and Y_1.

The result of this determination of moisture, based upon absolute weights, being compared with the indication of the drum N

used as a "throttling calorimeter," enables the truth of the "throttling" principle to be tested free of any question as to whether the sample of the steam acted on by the calorimeter represents the quality of the whole.

The results of this comparison are given by Table A, which shows that the true percentage of moisture of the steam leaving the calorimeter (column 4) determined by weight, agrees with that determined from the drum (column 5), by the usual process of estimating the moisture from the temperatures and pressures, the differences being within about two-tenths of a per cent. of the average of the two methods. This difference is within the accidental error of either method.

An example of the steps involved in calculating the percentage of moisture from an experiment is appended.

We may conclude, therefore, that a "throttling calorimeter" with its separating attachment will correctly indicate the proportion of moisture in any mixture which is made to pass through it. Hence the question of the erratic indication of small calorimeters which act upon a portion, or sample, only of the total steam under examination is reduced to this: *Can the sample of mixture of steam and water which a small "throttling calorimeter" draws through itself in a given time, out of a steam pipe or reservoir differ considerably in quality from that of the whole quantity of mixture which flows through the pipe in the same time?*

To answer this question we made the following experiments:

PART II.

EXPERIMENTS TO DETERMINE THE DIFFERENCE BETWEEN THE QUALITY OF A SAMPLE OF STEAM DRAWN FROM A THREE-INCH PIPE BY A "THROTTLING CALORIMETER" AND THAT OF THE TOTAL QUANTITY OF STEAM FLOWING THROUGH A PIPE.

A "throttling calorimeter" with its separator attachment, of the standard Barrus proportions, carefully calibrated for radiation with superheated steam, was attached at H, Fig. 1, by a vertical half-inch nipple tapped into the bottom of the three-inch pipe. The nipple projected two and one-half inches into the three-inch pipe. It was closed at its inner end, and perforated on its cylin-

drical surface with twelve one-eighth inch holes, the lower row of holes being three-eighths of an inch within the pipe. Steam from the boiler at 78.5 pounds pressure, which was superheated 30 degrees when passing B, received water at G at 60 degrees Fahrenheit, so that the total mixture flowing at E was 1,916 pounds per hour.

Assuming * that the injected water was raised to the temperature corresponding to the pressure, the per cent. of moisture at H was 21.0 per cent.; but the calorimeter gave the moisture at 54.6 per cent.

In the second experiment, in which 2,044 pounds of mixture flowed through the three-inch pipe per hour, the correct maximum moisture was 17.6 per cent., and by calorimeter 50.8 per cent. In these experiments the water was injected at G in a broken stream through one thirty-second of an inch perforations. It is probable, therefore, that the majority of it lay upon the bottom of the pipe.

These two experiments may, therefore, be taken as examples of the error to which "throttling calorimeters" are liable when considerable moisture may accumulate at the point in a steam pipe where the instrument is attached. To avoid this particular condition of the moisture we made the following experiments:

PART III.

EXPERIMENTS IN WHICH THE MOISTURE WAS THOROUGHLY MIXED WITH THE STEAM.

A Barrus "throttling calorimeter," L, without its separator, carefully calibrated for radiation, was attached at Z, Fig. 2, beyond the Stratton separator. Superheated steam at B was mixed with water at F, and the mixture sent through the system to the condenser *without draining the Stratton separator*. After the flow through the system had continued a short time the level of the water in the water glass of the separator remained unchanged, A constant mixture was, therefore, leaving the separator, and in

* This assumption makes the true moisture a maximum, and it, therefore, insures a minimum value for the discrepancy of the calorimeter.

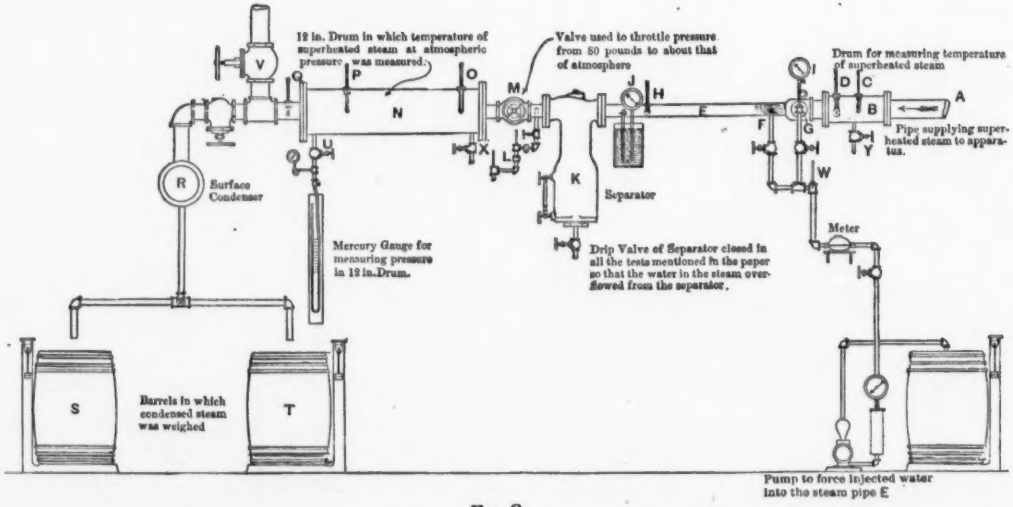

12 in. Drum in which temperature of superheated steam at atmospheric pressure was measured.
Valve used to throttle pressure from 80 pounds to about that of atmosphere
Drum for measuring temperature of superheated steam
Pipe supplying superheated steam to apparatus.
Surface Condenser
Mercury Gauge for measuring pressure in 12 in. Drum.
Separator
Drip Valve of Separator closed in all the tests mentioned in the paper so that the water in the steam overflowed from the separator.
Meter
Barrels in which condensed steam was weighed
Pump to force injected water into the steam pipe E

FIG. 2.

issuing from the outlet of the latter into the three-inch pipe at Z there must have been a thorough intermingling of the water and steam.

Under these conditions the "throttling calorimeter," attached with a vertical half-inch nipple (Fig. 1), closed at the inner end, and perforated with twelve seven-thirty-seconds-inch holes, none of which were less than three-quarters of an inch from the side of the main, a common arrangement of the instrument in practice—the results in lines 1 to 6, Table B, were obtained. These show that with from 2.5 to 36.5 true per cent. of moisture the calorimeter showed from 5.5 to 47.9 per cent.

Again, with the calorimeter attached with a horizontal half-inch nipple closed at its inner end and perforated with six seven-thirty-seconds-inch holes, none of which were less than three-quarters of an inch from the side of the main, the results in lines 7 to 12 were obtained. Whence it is seen that with from 2.3 to 57.2 true per cent. of moisture, the calorimeter gave from 6.3 to 46.9 per cent.

Again, the calorimeter was attached with a vertical half-inch nipple closed at its inner end, with a rectangular slot one-quarter of an inch wide by one inch long, as an orifice, the latter's center of height being at the level of the center of the three-inch pipe.

Then, by lines 13, 14 and 15, with the slot away from the boiler, with 1 per cent. of actual moisture, the calorimeter showed 5.6 per cent.; with the slot facing towards the boiler the true per cent. of moisture was 1.4 per cent., and the calorimeter gave 0.1 per cent., while with the slot facing at right angles to the current 1.2 per cent. of moisture in the steam caused the calorimeter to indicate 2.5 per cent.

Again, in lines 16 to 19, with a horizontal nipple with 6 holes seven thirty-seconds of an inch in diameter, with from 0.5 to 1.6 per cent. of actual moisture, the calorimeter showed from 1.0 per cent. to 3.6 per cent.

PART IV (*a*).

ABSTRACT OF RECORD OF TWO CALORIMETERS WITH MOVABLE NIPPLES APPLIED TO TWELVE-INCH MAIN DELIVERING ABOUT 500 HORSE POWER.

Calorimeter No. 1 at bottom of pipe.						Inches inner end of nipple was above inside of pipe.	Calorimeter No. 2, without separator.		
Duration of test, minutes.	Boiler pressure, pounds.	Corrected temperatures, degrees, Fahr.		Pounds of drip from separator per hour.	Per cent. of priming.		Corrected temperatures, degrees, Fahr.		Percentage of priming.
		Upper.	Lower.				Upper.	Lower.	
1	2	3	4	5	6	7	8	9	10
20	90	331	283	3.39	5.2	0	331	280	0.55
10	96	335	284	57.36	47.0	0.33	.....	.....	.....
10	99	338	286	30.00	32.0	0.66	338	287	0.13
10	96	334	285	11.73	15.5	1.00	335	287	0.05
10	94	334	286	0	0*	1.66	.....	.....	.....
2	90	330	284	0	0*	2.33	.....	.....	.....
3	95	334	286	0	0*	3.33	.....	.....	.....
3	95	335	286	0	0*	4.33	.....	.....	.....

* Radiation of calorimeter, 0.4 per cent.

PART IV (*b*).

EXPERIMENTS MADE TO PROVE THAT AS LITTLE AS ONE PER CENT. OF MOISTURE WILL SEPARATE ITSELF FROM STEAM IN A HORIZONTAL PIPE, AND, FLOWING ALONG THE BOTTOM OF THE LATTER, WILL ESCAPE THROUGH A "THROTTLING CALORIMETER," AND THEREBY TEND TO CAUSE THE PER CENT. OF MOISTURE SHOWN BY THE LATTER TO VARY CONSIDERABLY FROM THE TRUE AVERAGE PERCENTAGE IN THE STEAM MAIN.

The general arrangement of apparatus for conducting the tests on the three-inch horizontal pipe is represented in Fig. 3. The results are given in Table C.

Superheated steam entered at A and passed through a three-inch pipe surrounding a cooling pipe B. The cooling water entered at C and passed off at G. After passing the cooling pipe the steam passed through a device at D which thoroughly mixed the steam with the water. This consisted of two plates placed about one inch apart, in which were two holes about seven-eighths of an inch in diameter. The hole in the first plate encountered by the steam was at the bottom of the pipe, so that all moisture in the steam would be drawn from the bottom of the pipe. The

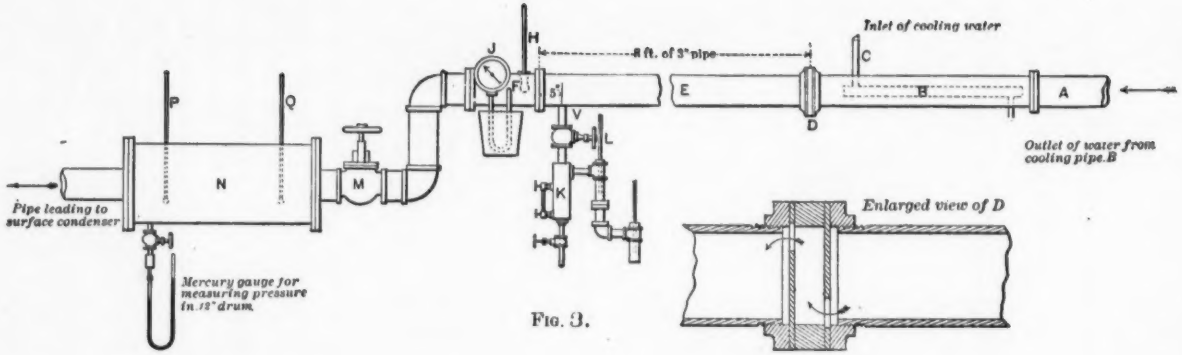

Inlet of cooling water
H
8 ft. of 3" pipe
C
J
F
3"
E
B
A
D
V
L
K
P
Q
N
M
Pipe leading to surface condenser
Mercury gauge for measuring pressure in 12" drum
Outlet of water from cooling pipe B
Enlarged view of D

FIG. 3.

steam and moisture then passed upward between the plates, and out of the hole in the second plate. The hole in the second plate was placed near the top so as to introduce the steam and moisture near the top of the three-inch pipe E. The calorimeter was attached at V. K is the separator portion of the calorimeter, and L the heat gauge. The temperature and pressure of the steam was measured on leaving the pipe E, by means of the thermometer H, and the pressure gauge J. The thermometer H was placed in a mercury well having an enlargement at its lower end and a thin neck. The steam was throttled by means of the valve M from a pressure of about 80 pounds above the atmosphere in the pipe E to about the pressure of the atmosphere in the twelve-inch drum N. The temperature of the steam after throttling was measured by a thermometer Q, placed in a mercury well, and by a thermometer P which came in direct contact with the steam. The pressure in the drum N was measured by means of a mercury gauge. The steam flowing into the drum N was led to a surface condenser and finally weighed.

The amount of moisture in the steam passing through the valve M was indicated by the amount of superheating in the twelve-inch drum N. This moisture, added to the moisture in the steam entering the Barrus calorimeter, gave the total moisture contained in the steam passing through the three-inch pipe. Corrections, determined directly by experiment, were made for all radiation. The factor of 0.48 for the specific heat of steam was employed in calculating the percentage of moisture; and special experiments were made to show how nearly this method would agree, in the case of the twelve-inch drum, with the experimental normal reading for dry steam. These experiments, from the nature of the apparatus, could be made only with steam just at the point of superheating, or with slightly superheated steam.

Three series of tests were made. In the first there was no mixing device placed at D. In these it was found that the thermometer H would indicate superheating with considerable moisture entering the calorimeter nozzle V. The second series of tests were made after adding the mixing device D. In the third

series of tests the three-inch pipe containing the cooling pipe B was lowered, together with the mixing device D, and the steam was made to pass through an S-shaped connection of three-inch pipe into the pipe E. This caused the steam which was admitted to E to pass upward through a vertical pipe, then turn through an elbow into the pipe E. The object of the latter arrangement was to make the mixture of steam and water enter the pipe E at the same velocity at which it flowed through the pipe E. When the steam and moisture entered the three-inch pipe directly from a seven-eighths-inch hole in the mixing device D, it was initially at a much greater velocity than the average velocity in the pipe E, but it was considered best to make tests in this way so as to have one set of tests in which the conditions were as severe as possible.

In all these tests no pains or expense were spared to secure accuracy. Green's thermometers were used, and were carefully calibrated in regard to their indications when immersed to the particular depths at which they were used in mercury wells. The standards of temperature were established by Regnault's steam tables, the necessary steam pressures being determined by three different bases. The radiation losses were determined with great care, and the question of the applicability of Regnault's value for the specific heat of steam was considered by a study of his memoirs, and by special experiments.

The details of these operations are given in papers by Prof. D. S. Jacobus, "Transactions American Society of Mechanical Engineers, Volume XVI," which, however, inadequately show the amount of painstaking labor and rare skill that he has supplied during the investigation.

TABLE A.

TESTS WITH UNIFORM PERCENTAGE OF MOISTURE FOR CALIBRATION OF TWELVE-INCH DRUM N, PLATE A, FOR USE ON A LARGE "THROTTLING CALORIMETER."

Duration of Experiments.	Pounds of dry steam per hour.	Horse-power at 30 pounds of steam per hour.	True percentage of moisture by weight.		Per cent. of moisture at 12" drum.	Boiler pressure, pounds.	Degrees of superheating, Fahrenheit.	Temperature of water leaving separator, degrees Fahrenheit.	Number of group.
			Entering separator.	Leaving separator.					
	1	2	3	4	5	6	7	8	9
Av'ge of 5 experiments aggre'ing 150 min...	608.0	20.27	27.0	−0.03	−0.14	80.14	26.84	329.64	1
" " 3 " " 80 "	1537.8	51.26	21.5	2.15	1.87	81.13	27.23	324.40	2
" " 2 " " 80 "	1689.6	54.32	16.7	0.92	0.90	79.85	37.85	323.68	3
" " 2 " " 70 "	1749.3	58.31	12.7	0.54	0.45	79.85	36.95	323.56	4
" " 2 " " 60 "	1836.1	61.20	14.4	0.75	0.35	80.00	42.85	323.60	5
" " 2 " " 38 "	2109.2	70.31	30.3	2.20	2.00	79.75	34.25	323.35	6
" " 2 " " 50 "	2315.3	77.18	30.7	2.40	2.10	79.90	25.70	323.55	7
" " 1 " " 31 "	3033.9	101.13	7.7	0.21	0.30	80.00	27.70	323.90	8

TABLE B.

COMPARISON OF ACTUAL PERCENTAGES OF MOISTURE WITH AMOUNTS INDICATED BY A "THROTTLING CALORIMETER," STEAM PASSING THROUGH A THREE-INCH HORIZONTAL PIPE.

Number of test.	Character of Nozzle.	Steam passing through pipe per hour including moisture shown in column 6.	Pressure of steam in pounds per sq. inch above atmosphere.	Percentage of moisture by Barrus calorimeter.	Correct percentage of moisture determined by weighing water injected into steam pipe.	Remarks.
1		1698	80	5.5	2.5	
2		1877	80	9.3	3.3	
3	Vertical nozzle No. 1, with 12 holes 1/32 inch diameter.	1768	80	11.1	4.7	
4		1788	80	20.9	10.9	
5		2003	80	31.8	19.1	
6		2381	80	47.9	36.5	
7		1538	90	6.3	2.3	Separator of calorimeter and heat gauge, both in use.
8		1586	80	8.4	3.2	
9	Horizontal nozzle No. 3, with 6 holes 1/32 inch diameter.	1525	80	14.6	8.8	
10		1637	80	17.8	10.1	
11		1745	80	37.4	23.0	
12		2187	80	46.9	37.2	
13	Nozzle No. 4, slot away from current.....	1577	80	5.6	1.0	
14	" " " toward current.....	1576	80	0.1	1.4	
15	" " " at right angles to cur'nt	1578	80	2.5	1.2	
16		1810	80	1.0	0.5	
17	Horizontal nozzle No. 3, with 6 holes 1/32 inch diameter.*	1815	80	1.5	0.8	Only heat gauge of calorimeter in use.
18		1818	80	2.2	1.0	
19		1830	80	3.6	1.6	

* In these tests the true percentages of moisture given in column 6 were calculated from the superheating of the steam in the 12-inch drum, which was shown to give the same results as those obtained by weighing the water injected.

TABLE C.

PERCENTAGE OF TOTAL MOISTURE ENTERING A THREE-INCH HORIZONTAL STEAM PIPE THAT IS REMOVED BY A ONE-HALF-INCH DRIP PIPE.

The moisture in each case was either thoroughly mingled with the steam or the greater part of it was near the top of the three-inch pipe at a point eight feet distant from the one-half-inch drip pipe. Much of the moisture had, therefore, to fall through a distance nealy equal to the diameter of the three-inch pipe before it was drawn out at the one half-inch drip pipe.

Conditions under which the tests were made.	Number of Test.	Velocity of steam in three-inch pipe in feet per second.	Percentage of moisture in steam passing through three-inch pipe.		Percentage of total moisture removed by the half-inch drip pipe leading to the Barrus calorimeter.
			Before reaching drip pipe.	After passing drip pipe.*	
1	2	3	4	5	6
First Series of Tests. Moisture produced by the cooling pipe marked B in Fig. 1. No mixing device at D.	1	65.1	3.9	2.2	45.6
	2	64.7	1.9	0.9	55.7
	3	63.3	1.5	0.4	71.7
	4	52.3	1.6	0.3	84.4
	5	52.2	4.2	1.6	62.8
	6	41.9	3.3	0.3	91.5
	7	38.1	4.8	0.6	88.6
	8	38.1	2.6	0.5	82.8
	9	38.1	2.4	0.4	85.6
	10	38.1	0.3	0.0	100.0
Second Series of Tests, in which a mixing device was placed at D to thoroughly mingle the steam and water.	11	38.0	1.6	0.2	89.0
	12	38.0	0.4	—0.1	100.0
	13	24.9	4.8	0.1	98.7
	14	24.8	3.1	—0.1	100.0
	15	24.5	8.2	0.5	95.0
	16	19.2	8.8	0.5	95.3
	17	16.0	8.8	0.3	97.4
	18	16.0	6.6	0.1	98.1
	19	15.9	1.0	—0.1	100.0
	20	15.6	5.4	—0.1	100.0
Third Series of Tests, in which the steam and entrained moisture was supplied through a vertical three-inch pipe and flowed through an elbow into the three-inch horizontal pipe.	21	43.1	3.5	1.2	67.3
	22	42.7	2.3	0.7	68.8
	23	35.9	1.3	0.2	85.2
	24	35.8	3.4	0.7	80.8
	25	31.1	3.5	0.3	91.7
	26	31.1	2.1	0.1	95.0
	27	20.9	12.1	0.5	96.8
	28	20.6	7.8	0.0	100.0
	29	20.5	2.5	—0.1	100.0
	30	20.2	3.8	0.1	97.1
	31	15.8	5.6	—0.2	100.0
	32	15.4	8.7	—0.2	100.0
Special Tests in Third Series, in which a plate was placed over the drip pipe leading to the calorimeter so as to collect all moisture that was near the bottom of the pipe.	33	42.1	3.5	1.1	66.6
	34	42.1	2.2	1.2	49.4
	35	41.9	2.4	1.1	57.4
	36	38.1	2.4	0.6	77.8
	37	34.3	2.5	0.1	96.7
	38	33.1	3.4	0.0	100.0
	39	26.9	7.3	—0.1	100.0
	40	26.8	4.8	0.0	100.0
	41	20.5	4.3	—0.1	100.0
	42	20.2	13.1	0.4	97.4
	43	20.2	4.9	0.0	100.0

* The percentages of priming given in this column are calculated from the superheating in the twelve-inch drum, and are correct to within about one-fifth per cent. The minus values are either accidental discrepancies or they are caused by the fact that the steam was initially superheated, and tended to retain the property of producing a slightly higher "normal reading" than that given by the theoretical formula.

METHOD OF COMPUTING THE TRUE PERCENTAGE OF MOISTURE IN THE STEAM ENTERING AND LEAVING THE SEPARATOR.

For Part I.

The method which has already been described consisted in determining the percentage of moisture in the mixture of steam and the known weight of injected water. The data and calculations in detail for test, Group 8, Table A, are as follows:

1. Duration for selected interval for which the average data are obtained, in minutes	31
2. Total steam and entrained water leaving the separator K, in pounds, per hour	3,040
3. Water drawn from separator, in pounds, per hour	248.2
4. Total weight of steam and entrained water entering separator, in pounds, per hour = W	3,288.2
5. Water injected at P, in pounds, per hour = w	232.0
6. Temperature of water injected at F, in degrees Fahrenheit = t'	69
7. Pressure of steam at J, in pounds, per square inch above atmosphere	80
8. Sensible heat of steam corresponding to pressure at J in B.T.U. = h	326.9
9. Temperature of steam corresponding to pressure at J, in degrees Fahrenheit = t''	323.6
10. Latent heat of steam corresponding to pressure at J, in degrees Fahrenheit = L	885.7
11. Temperature of superheated steam before injecting water, as registered by the thermometer D, in degrees Fahrenheit = t'''	351.3
12. Weight of steam condensed by the water injected in pounds $\frac{w(h-t')-0.47(t''-t'')(W-w)}{L}$ *	22.6
13. Total weight of water in the mixture of steam and water = line 5 + line 12	254.6
14. Percentage of moisture in steam entering the separator = line 13 × 100 ÷ line 4	7.7
15. Water remaining in steam leaving separator in pounds per hour = line 13 — line 3	6.4
16. True percentage of moisture in steam leaving the separator = line 15 × 100 ÷ line 2	0.21

CALCULATION OF THE PERCENTAGE OF MOISTURE INDICATED BY THE SUPERHEATING OBSERVED IN THE TWELVE-INCH DRUM.

For Experiment: Group 8, Table A.

1. Pressure of steam before throttling, in pounds per square inch above atmosphere = p_1	80.0

* The factor of 0.47 was determined by experiment so as to include all radiation effects.

2. Pressure of steam after throttling, in pounds per square inch above atmosphere $= p_2$ 3.2
3. Sensible heat above zero, degrees Fahrenheit, corresponding to pressure $p_1 = h_1$ 326.9
4. Latent heat corresponding to pressure $p_1 = L_1$ 885.7
5. Total heat above zero, degrees Fahrenheit, corresponding to pressure $p_2 = H_2$ 1,181.7
6. Temperature corresponding to pressure $p_2 = t_2$ 222.1
7. Temperature of superheated steam after throttling $= S_2$ 281.4
8. Quality of steam $= \frac{H_2 + 0.48\,(S_2 - t_2) - h_1}{L_1}$ 0.997
9. Percentage of priming $= 100\,(1 -$line 8$)$ 0.3

MEASUREMENT OF TEMPERATURES OF STEAM.

By Prof. D. S. Jacobus, M. E.

[Reprinted from "Stevens Indicator," January 1896.]

In boiler and in calorimeter tests it is often necessary to measure the temperature of steam. This is usually done by inserting a mercury thermometer in a well placed in the steam main, or pipe, through which the steam passes. Mercury or oil is used in the well to transmit the heat to the bulb of the thermometer.

The object of this paper is to present experiments which were made to determine how nearly thermometers used in this way would register the correct temperature of the steam. The magnitude of the errors which may be involved by not heating the portions of the stems of the thermometers which project above the wells will also be discussed.

These experiments indicated that mercury wells of ordinary patterns will give the exact temperature of the saturated steam surrounding them, no matter what their thickness or form may be, provided they project into the steam space 1½ inches or more; whereas, with superheated steam, the temperature of the wells will be affected by their size and form.

It was also demonstrated that oil was much inferior to mercury for use in the wells, as a thermometer placed in a well containing oil responded more slowly to changes of temperature than if placed in a well containing mercury. In the case of a short well the use of oil would cause the thermometer to register too low, on account of the fact that the oil is such a poor conductor that the heat would not be imparted to the bulb rapidly enough to make up for the heat transmitted to, and radiated from, the por-

tion of the stem of the thermometer which projected above the well.

In all cases a correction must be made if the mercury in the stem of the thermometer projects above the well. This correction is sometimes a large one. For example, in a thermometer used to measure the temperature of steam at the pressure of 60 pounds above the atmosphere, in which the column of mercury projecting above the well was about 9 inches long, and the reading to which the thermometer was immersed in the well was 40° Fahr., the correction amounted to 5° Fahr.

To eliminate the error due to not heating the stems of the thermometers, it has been our practice to calibrate the thermometers in the wells in which they are to be used, or in wells of the same depth, surrounded with saturated steam at a known pressure, and, therefore, at a known temperature. For example, if the number of degrees of superheating in the steam leaving a boiler is to be measured, the reading of the thermometer, with steam which is slowly condensing in the pipe, is determined, and the difference of the readings at a given pressure, for the steam which is slowly condensing and for the superheated steam, gives the number of degrees of superheating. To obtain the reading for steam which is slowly condensing, the main is allowed to remain open to the boiler, and is shut off at a point beyond the thermometer, so that the steam in the main is practically in a state of rest. If the steam is superheated at the time the main is closed at a point beyond the thermometer, the temperature registered by the thermometer for a given steam pressure will gradually fall until the reading of the thermometer is constant for a given steam pressure, and this constant reading for a given pressure is the reading for saturated steam.

This method was pursued in the test of the Pawtucket engine with saturated and superheated steam,* and since that time all thermometers we have used in steam pipes have been corrected in a similar way.

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* Transactions A. S. M. E., Vol. xiii, p. 194.

The readings of the Bristol thermometer* are independent of the amount to which the capillary tube leading from the bulb to the pressure recording divice is heated ; the Bristol thermometer, therefore, possesses an advantage over a mercury thermometer in this respect. If used to measure the temperature of steam, the bulb of the Bristol thermometer must be placed in direct contact with the steam, or it must be used in a well containing mercury. If used in a well containing oil, there may be a considerable error, which is not caused through any fault of the instrument, but from the fact that the oil is a poor conductor of heat.

In addition to determining the relative sensitiveness of thermometers placed in wells which contained oil and mercury, a comparison was made of thermometers placed in a current of superheated steam, which came in direct contact with their bulbs, and of thermometers used in wells. The sensitiveness of the Bristol Recording Thermometer was also compared with the sensitiveness of mercury thermometers used under the above conditions.

The bulb of the Bristol thermometer contained amylic alcohol. The bulb was three-eighths of an inch in diameter and five inches long.

The tests indicated that when the thermometers were placed directly in a current of superheated steam, and the amount of steam flowing by them was considerable, the Bristol thermometer was as sensitive as the mercury thermometer. The Bristol thermometer, with the bulb placed directly in the steam, was more sensitive than a mercury thermometer placed in a mercury well.

If the flow of steam was a limited one, there were conditions under which a sudden change would not be recorded as rapidly

* The Bristol thermometer consists of a bulb of considerable size containing a volatile fluid, which is partly evaporated on being heated to the temperature which is to be measured. The pressure of the vapor is communicated to a gauge by means of a tube of very fine bore. The quantity of liquid in the bulb is such that it is not wholly evaporated at the maximum temperature for which the instrument is designed, so that the pressures recorded by the gauge correspond to the temperatures of the saturated vapor in the bulb. The pressure gauge is graduated so that the readings represent temperatures instead of pressures.

by the Bristol thermometer as by a mercury thermometer placed in direct contact with the steam. The tardiness of the Bristol thermometer in the latter case was due to the heat required to evaporate the alcohol in the bulb. This effect will not be appreciable in ordinary use, and has but little influence for a rate of flow of one pound of superheated steam per minute, which is about the rate of flow in a Barrus calorimeter of the usual construction.

When used in a Barrus calorimeter the Bristol thermometer responds much more quickly to a change of conditions than a mercury thermometer placed in a well containing mercury; and a mercury thermometer in a well containing mercury responds more quickly than one placed in a well containing oil.

No tests were made to determine if the readings of the Bristol thermometer would be correct after a long period of use. All the results given in this paper are for a thermometer specially made for the purpose, the temperature scale of which was determined and graduated just before making the tests.

The temperatures given in the ordinary steam tables are those registered by an air thermometer; consequently, even if we had the correct readings with a mercury thermometer, they would have to be altered so as to correspond to the readings of an air thermometer, before the results could be used for interpolation in a steam table, or for obtaining the number of degrees of superheating. In calorimetric work the temperatures must also be those registered by an air thermometer. If, therefore, the readings of a mercury thermometer have been determined under known pressures of saturated steam, and consequently at known temperatures by an air thermometer, we can obtain the corrections which will reduce the readings of the mercury thermometer to equivalent ones for an air thermometer. These are the corrections that are required in ordinary work.

We will describe the apparatus now in use at the Stevens Institute for this purpose,* and afterward discuss the experiments in

* A description of this apparatus was presented at the New York meeting of the American Society of Mechanical Engineers, and will appear in Vol. XVII of their Transactions.

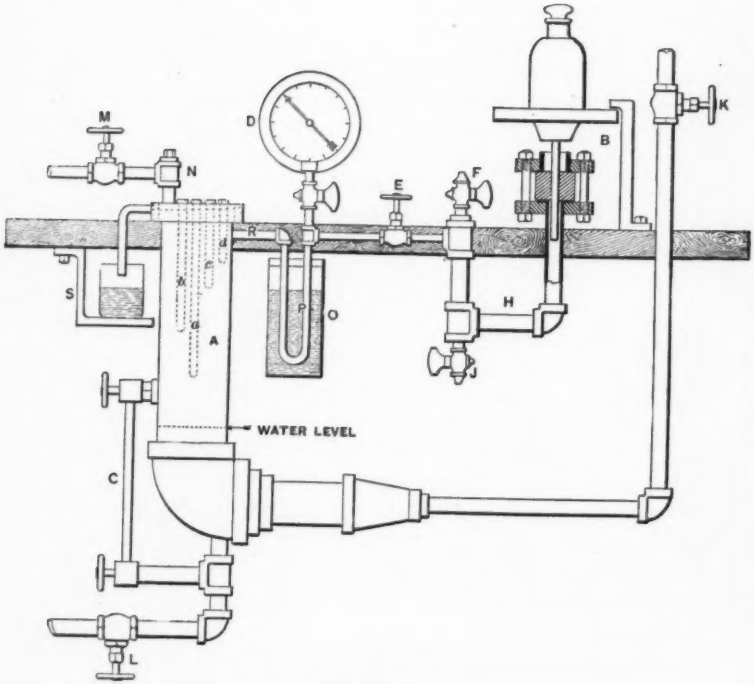

Figure 1.

detail which lead up to the conclusion presented in the first part of this paper. The apparatus is shown in Fig. 1.

A is a reservoir formed of a length of 6-inch pipe, the top of which is closed with a cap. Seven mercury wells of various lengths, four of which are marked *a*, *b*, *c* and *d* in the sketch, are inserted in the cap. Steam is brought to a known pressure in the reservoir A, and on entering, passes through water at the bottom of the reservoir. The water glass C indicates the height of the water. The pressure is measured by means of the plug-and-weight device B. The bottom of the plug is on the same level as the pipe R. D is a gauge which is used to show the approximate pressure. The U-shaped pipe H is filled with oil. Before measuring the pressure the petcock F is opened slightly, in order to remove any air that may be lodged in the small pipe leading to the pipe H. The siphon P is cooled by water contained in the can O. The petcock J is used to remove any water that may collect at the lower part of the pipe H, after which the pipe is refilled with oil at F. The accumulation of water in H is caused by leakage of oil around the plug of the weight device, and as this is a small amount, there is but little water drawn from the petcock J.

The valve M is opened slightly throughout the tests, to permit steam to circulate continuously throughout the apparatus.

K is a throttle valve for the adjustment of the steam pressure in the reservoir A. The plug N is removed for calibrations at atmospheric pressure. The valve L is used to adjust the water level. S is a vessel to receive any mercury that may overflow from the wells.

In measuring the pressure by means of the weight device B the pan is spun around so as to eliminate the friction. The diameter of the plug is 0.5 of an inch, and of the hole 0.5005 of an inch, both being ground true. The average diameter of the hole and plug is used in calculating the pressure. The difference in the pressure, if the diameter of the plug, or the diameter of the hole, were employed instead of the average diameter, would amount to about one-tenth of a pound in 100, and the corre-

sponding variation in temperature would be about one-sixteenth of a degree Fahr.

The weights, which are sealed bottles filled with shot, were adjusted to correspond with a standard set of kilogramme weights which were in turn, compared with weights made by the Fairbanks Company.

The errors due to not heating the portion of the stem of a thermometer which projects above a mercury well diminish if the thermometer is placed in a deeper well, and disappear when it is immersed so that all the mercury in the stem is heated to the maximum temperature. For example, with a thermometer in which there was an error of $7\frac{1}{4}°$ Fahr., for steam at a pressure of 120 pounds per square inch above the atmosphere, when placed in a well $1\frac{3}{4}$ inches deep, the error was $6\frac{3}{4}$ degrees when immersed in a $2\frac{1}{2}$-inch well; $5\frac{3}{4}$ degrees in a well $3\frac{3}{4}$ inches deep; $4\frac{3}{4}$ degrees in a well $5\frac{3}{4}$ inches deep; $2\frac{1}{4}$ degrees in a well $9\frac{3}{4}$ inches deep, and the thermometer read correctly when entirely immersed in the well.

It is interesting to note how nearly the mercury thermometers in use to-day agree with those employed by Regnault in measuring the temperatures of saturated steam.

The readings, for given steam pressures, of six thermometers made by Mr. H. J. Green, are given in Table 1.* All the thermometers, with one exception, had been used in previous tests. The results in the table are corrected for the variations at 212° Fahr., due to continued use, and in each case the thermometers were submerged in the wells so as to heat the entire amount of mercury in the stems. The graduations were such that the temperatures could not be read closer than one-quarter of a degree Fahr., and, therefore, the maximum error, due to reading, was one-half of a degree Fahr. The average reading of Mr. Green's thermometers at each pressure differed less than one-half of a degree Fahr. from the readings of Regnault's thermometers, which indicated that Mr. Green's thermometers agreed with those of Regnault to within the error of reading their scales.

* This table was also presented at the meeting of the A. S. M. E, and will appear in Vol. XVII of their Transactions.

TABLE I.

READINGS OF MERCURY THERMOMETERS IN DEGREES FAHRENHEIT CORRESPONDING TO VARIOUS STEAM PRESSURES. COMPARISON OF READINGS OF THERMOMETERS MADE BY H. J. GREEN, WITH READINGS OF MERCURY THERMOMETERS USED BY REGNAULT IN MEASURING THE TEMPERATURE OF SATURATED STEAM.

Number of thermometer.		Pressures at which readings were taken, in pounds per square inch above atmosphere. Pressure of atmosphere, 14 70 pounds.				
		120	100	80	60	40
1		2	3	4	5	6
817		351 3/4	339 1/4	325 1/4	308 1/2	287 3/4
900		351 1/4	338 1/4	324 1/4	307 3/4	287 1/4
463		351 3/4	338 3/4	324 3/4	308	287 1/4
461		351 1/4	338 1/2	324 1/2	308	287 1/4
* 831		350 1/2	338	324 1/4	308	287
* 821		351	338 3/4	324 3/4	308 1/2	287 1/2
Average of first four.....		351 5	338 7	324 7	308 1	287.4
Reading of Regnault's thermometers.	Mercury.	351 6	339 1	324 8	308.1	287.4
	Air †	349 8	337 6	323 7	307.1	286.5

Thermometers.									Degrees Fahrenheit.
No. 817 has a stem about 19 inches long graduated from									27 to 430
" 900	"	"	"	16	"	"	"	"	15 " 450
" 463	"	"	"	17 1/2	"	"	"	"	94 " 406
" 461	"	"	"	11 1/2	"	"	"	"	192 " 406
" 831	"	"	"	15 1/2	"	"	"	"	90 " 610
" 821	"	"	"	16	"	"	"	"	80 " 620

* Not included in average, as the graduations were closer together than in the other thermometers, and the probable error of reading was therefore greater.

† The temperatures measured by the air thermometers are those given in the ordinary steam tables.

The bulbs of the thermometers made by Mr. Green are all of the same kind of glass. After a long investigation of the matter, Mr. Green, in 1889, had made for him by Messrs. Schott & Gen, of Jena, Germany, a pot of glass supposed to be of the same

composition as that used by Crafts in his experiments on high-temperature thermometers,* Weidman,† Pernet,‡ and others. The peculiarity of this glass is due to the fact that it contains about 7 per cent. of oxide of zinc, and no lead. This one pot of glass has been used to form the bulbs only of his thermometers, and he considers that he will have enough bulb glass from this one pot to last a life time.

As the amount of mercury in the stem of a thermometer is a small fraction of that in the bulb, the expansion of the glass in the bulb practically governs the variations in the readings of the thermometers due to the expansion of the glass. By employing the same glass for all the bulbs, Mr. Green has, therefore, been able to produce thermometers which are exactly comparable with each other. That this is the fact is substantiated by the results of the tests given in Table I.

The greatest variation at 212 degrees found in any of the thermometers was three-quarters of a degree Fahr. Thermometers No. 461 and 463 had been used in a test which was made at intervals, one or two days apart, of about three hours each, and which extended over two months. In this test thermometer No. 461 was placed in direct contact with a current of superheated steam at atmospheric pressure. The temperature of the steam averaged about 270° Fahr., and was continually fluctuating between a range of about 250 and 290° Fahr. Thermometer No. 463 was used for a portion of the time under the same conditions as No. 461, and the remainder of the time it was placed in a mercury well for measuring a temperature of from 325° to 350° Fahr. No. 900 was used under the same conditions as No. 461, in a test which extended over about one week, and was placed in a mercury well at about 325° Fahr. in another test of the same duration.

Thermometers No. 821 and 831 had been used for miscella-

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* Comptes Rendus, Vol. xcv, 1882, page 836, and many other papers on the subject of thermometers.

† Annalen der Physik und Chemie, 1886, Vol. xxix, page 214.

‡ Comptes Rendus, Vol. xci, 1880, page 471. Journal de Physique, 1881, page 520, etc.

neous work, one having been employed to measure the flue temperature in a boiler test, where it was heated, a number of times, over 500° Fahr., and some times as high as 600° Fahr.

No. 817 had been in use but little before taking the readings given in Table I.

All thermometers were raised and lowered in temperature a number of times before taking the readings, so as to produce the corresponding amount of depression, and insure constant readings at given temperatures.

Three-quarters of a degree variation in the readings is a small change for thermometers used under the above conditions, and shows that the glass in the bulbs was thoroughly annealed.

Mr. Green's method of annealing high-temperature thermometers is to place them in lampblack, and subject them to the temperature of 450° Fahr., continuously, for 150 hours, cooling them very slowly at the end of this time. His thermometers are graduated by determining points at 32° Fahr. and 212° Fahr., and calibrating for all other temperatures, so that each degree represents an equal volume of mercury. The 32-degree point is obtained by allowing the thermometer to remain at least 30 hours in the ice, to destroy any depression due to ordinary temperature changes. The 212-degree point is obtained after the 32-degree point. In obtaining the 212-degree point the thermometer is placed in the steam, and removed a number of times until the corresponding depression is produced, and the reading is constant.

Experiments in Detail.

EXPERIMENTS MADE TO PROVE THAT MERCURY WELLS INDICATE THE EXACT TEMPERATURE OF SATURATED STEAM.

In the first experiment a thermometer E, Fig. 2, was inserted through a stuffing box C so that the bulb came in direct contact with steam at 80 pounds pressure per square inch above the atmosphere. The reading of this thermometer was determined at a given pressure, measured by the gauge D, together with the reading of another thermometer F placed in the mercury well A. After recording a number of readings the thermometer E

was removed from the stuffing box and placed in the mercury well B and a second set of readings was taken. After correcting for the variation in the reading of E, due to the direct pressure of the steam on the bulb, the reading when used in the mercury well was found to be the same as when the bulb came in direct contact with the steam.

The thermometer E was heated to the same height on the stem when placed in the mercury well B, as when it passed through the stuffing box C. The well B was 3 inches deep. The variation in the reading of the thermometer E, due to the steam pressure acting directly on the bulb, was determined before and after the time it was used in the stuffing box C, by placing it in a similar stuffing-box attached to a reservoir of oil. The oil in the reservoir was heated until the thermometer registered the same as when placed in the stuffing box C. The pressure of the oil in the reservoir was then raised quickly to 80 pounds per square inch, and the variation in the reading of the thermometer was noted. The pressure was then lowered, and the variation in the reading again noted. This operation was repeated a number of times, and it was found that the error due to an increase of pressure of 80 pounds per square inch was exactly 1° Fahr.

Other experiments demonstrated that the wells A and B registered the correct temperature of steam at atmospheric pressure.

The experiments just described proved that a well 3 inches deep indicated the correct temperature of the steam. The next step was to compare wells of different depths.

The wells compared were those in the reservoir A, Fig. 1. Two special thermometers were made in which the reading for steam at 80 pounds pressure, of saturated steam, would be about $1\frac{1}{4}$ inches from the bottom of the bulb, and which could be easily read to one-quarter of a degree Fahr. This allowed all the mercury in the stems to be heated when the thermometers were placed in short wells.

The two special thermometers were placed in an air oven, together with a thermometer in which the reading for 80 pounds steam pressure was $16\frac{1}{2}$ inches from the bottom of the bulb, and the relative readings of the three thermometers were determined.

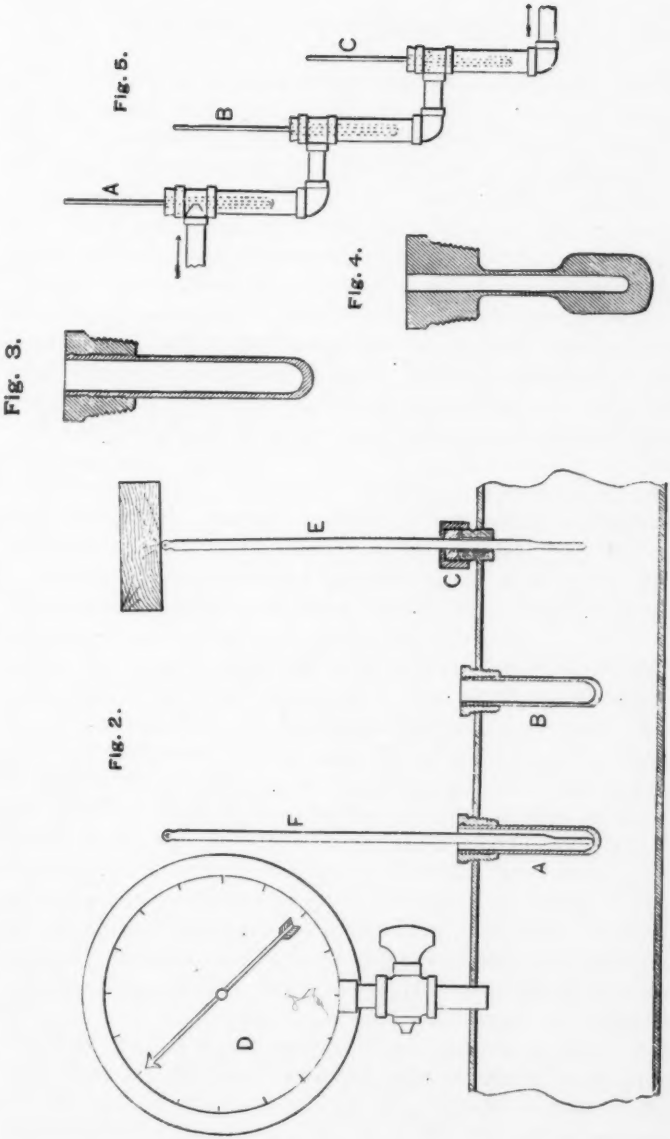


Fig. 5.
C
B
A
Fig. 4.
Fig. 3.
Fig. 2.
E
C
B
F
A
D

The short thermometers were then placed in mercury wells 1¾ and 2½ inches deep, which projected ¾ and 1½ inches, respectively, into the steam space, and the long thermometer was placed in a deep well, so that all the mercury in the stem was heated.

The relative readings for one of the short special thermometers placed in the well, which projected 1½ inches into the steam space, and of the long thermometer when submerged in the deep well were the same for 80 pounds pressure of saturated steam as the readings when uniformly heated to the same temperature in the air oven; which proved that the 1½-inch well and the deep well indicated the same temperature. The well which projected three-quarters of an inch into the steam space indicated between one-eighth and one-quarter of a degree Fahr. lower than the deep mercury well.

It therefore follows that wells of the pattern used in the tests will indicate the true temperatures with saturated steam, provided they project 1½ inches into the steam space.

The wells were made from ⅜-inch steam pipe, the lower ends being closed by welding, and the tops screwed into ¾-inch bushings, as shown in Fig. 3.

The air oven, in which the short special thermometers were compared with a long thermometer, was provided with a glass window, through which the thermometers could be read. The bulbs of the thermometers were placed side by side. Other thermometers were placed in the oven with their bulbs in contact with the stem of the long thermometer, in order to prove that the latter was uniformly heated throughout its entire length. Readings were taken at intervals of a minute until the relative indications of the thermometers were constant. The thermometers were then removed from the oven, and their positions changed, after which they were compared a second time. No difference was found, due to change in the position of the thermometers. The air which entered the oven was heated by means of a direct flame of a Bunsen burner. The circulation of air through the oven was considerable and the air was deflected and thoroughly mingled by means of a system of baffle plates, so that the temperature throughout the oven was very nearly constant.

A second method of comparing wells of different depths was as follows:

A special thermometer was made, in which the reading for saturated steam at 80 pounds pressure was about 18 inches from the bottom of the bulb. The bulb of this thermometer was made large in proportion to the bore of the stem, and the degree marks were about half an inch apart. The stem was graduated to one-tenth of a degree Fahrenheit. The correction, in degrees, for the portion of the stem which is not heated was much smaller in this thermometer than in one of the same length of ordinary construction. The actual amount of the correction for the special thermometer was about one-tenth that for the other thermometers used in the tests, because the one-tenth degree marks on the special thermometer were about the same distance apart as the degree marks on the ordinary thermometers.

The difference in the reading of this thermometer, when placed in a well which projected $2\frac{3}{4}$ inches in the steam space and when placed in a well 18 inches deep, so that the entire amount of mercury in the steam was heated, was 0.6° Fahrenheit. The theoretical correction, determined by employing the equation which follows, was exactly this amount, and, therefore, the wells were of the same temperature to within the error involved in estimating the average temperature of the portion of the stem of the thermometer which projected above the well. This temperature was measured by means of two small thermometers, the bulbs of which were placed against the side of the stem projecting above the well. If the error of estimating this temperature had been 10° Fahrenheit, the corresponding difference in the correction, calculated by means of the equation, would have been 0.03 of a degree Fahrenheit, and it is probable that the temperature of the steam was estimated closer than within 10 degrees, so that there could not have been over 0.03 of a degree difference in the short and long mercury well.

The formula for correcting for the portion of the stem which projects above the well is as follows:

$$x = 0.000087\ (t_1 - t_3)\ (t_1 - t_2)$$

in which

x = correction in degrees Fahrenheit.

t_1 = reading of thermometer in degrees Fahrenheit.

t_2 = reading to which the stem is immersed, in degrees Fahrenheit.

t_3 = average temperature of the mercury in the portion of the stem which is not immersed.

0.000087 = factor found by a direct experiment made to determine apparent expansion of mercury in the glass stem of the thermometer, and corrected to allow for variation of the density of mercury at the temperature of the experiment, and the temperature corresponding to the steam pressure of 80 pounds per square inch above the atmosphere.

RELATIVE SENSITIVENESS OF MERCURY THERMOMETER USED IN OIL AND IN MERCURY WELLS FOR MEASURING THE TEMPERATURE OF SATURATED STEAM.

The relative sensitiveness of thermometers when placed in wells containing oil and mercury, which are surrounded by saturated steam, was determined by placing thermometers in the 3-inch wells A and B, Fig. 2. The well A contained oil, and the well B mercury. The thermometers were the same in size and in their graduations.

After performing one set of experiments the oil was removed from the well A and replaced by mercury, and the mercury in B was replaced by oil. The experiments were then repeated. The pressure was maintained constant, as shown by the gauge D, and by observing the temperature registered by the thermometer C. It was found that about seven minutes elapsed before the thermometer placed in the well containing oil would register within one-quarter of a degree Fahr. of the final maximum reading; whereas less than one minute was required for the thermometer placed in the mercury well. The thermometers were cooled to the temperature of the air in the room, which was 80° Fahr., before they were placed in the wells.

Another experiment consisted in varying the pressure of the saturated steam. If the pressure was maintained at 70 pounds per square inch until the readings of the thermometers were constant, and then raised to 80 pounds in one minute, the ther-

mometer in the oil well, instead of showing an increase of temperature of 8° Fahr., as it should have done, provided it correctly registered the increase in temperature of the steam, indicated a rise of only 4° Fahr. The thermometer in the mercury well indicated the correct increase, or 8° Fahr.

ERRORS DUE TO USING OIL INSTEAD OF MERCURY IN THE WELLS

The thermometer placed in the 3-inch well containing oil, when subjected to a steam pressure of 75 pounds per square inch above the atmosphere, indicated a temperature of about 2 degrees lower than the thermometer placed in the well containing mercury. This was checked by reversing the thermometers in the wells. The difference was caused by the fact that oil is such a poor conductor, compared with mercury, that the heat supplied to the bulb of the thermometer placed in the oil well was insufficient to overcome the effect of the radiation of the stem of the thermometer which projected above the well; whereas with the mercury well there was a much more rapid conduction of heat to the bulb, and consequently no appreciable error.

If the bulb of the Bristol thermometer be placed in a well containing oil, there will be an error due to conduction and radiation of the heat from the small tube leading to the bulb. When placed in a well 7 inches deep, so that there was 2 inches of oil over the top of the bulb, the error due to this cause was about $1\frac{1}{2}$° Fahrenheit. The sensitiveness of the Bristol thermometer, in recording rapid changes of temperature, is also greatly impaired when the bulb is placed in a well containing oil. In its present form the bulb of the Bristol thermometer is of brass or copper, and cannot be used in a well containing mercury, so that for accurate work it is advisable to place the bulb in direct contact with the steam.

TESTS OF RELATIVE SENSITIVENESS OF MERCURY THERMOMETERS AND OF THE BRISTOL THERMOMETER WITH SUPERHEATED STEAM.

Tests of relative sensitiveness were also made with superheated steam. To do this, a special throttling calorimeter, simi-

lar to the Barrus, was constructed, in which the pipe, into which the superheated steam at low pressure flowed after passing the orifice, was made 2 inches in diameter. This allowed two wells to be placed side by side in the superheated steam, at a distance of about half an inch apart. The orifice of the calorimeter was made of such a diameter that two pounds per minute, or twice the ordinary amount of steam, flowed through the calorimeter. Tests were first made with oil in one of the wells and mercury in the other, a mercury thermometer being placed in each well. After these tests, one well was removed and replaced by the bulb of the Bristol thermometer, and a comparison was made of the Bristol thermometer and a mercury thermometer placed in a well containing mercury. Finally the second well was removed, and the Bristol thermometer was compared with a mercury thermometer which came in direct contact with the superheated steam.

The calorimeter was supplied with steam drawn from a vertical nipple with no side holes, which projected upward for several inches in a short length of horizontal 4-inch pipe. The pipe was well drained. The steam obtained in this way was found, by previous tests, to be uniformly dry. The steam was led to the calorimeter by a horizontal length of half-inch pipe about two feet long, and uncovered. The calorimeter itself was well covered with hair felt.

In making the experiments the calorimeter was first run for about fifteen minutes at a given steam pressure of about 80 pounds per square inch, at the end of which time the readings of the thermometers were constant. Water was then poured slowly on the horizontal length of half-inch pipe leading to the calorimeter, in order to vary the amount of superheating in the steam after passing the orifice, or in some tests a piece of wet waste was placed on the pipe for the same purpose.

It was found that a thermometer placed in a well containing mercury indicated greater changes of temperature, and responded much more quickly, than a thermometer placed in a well containing oil. For example, in one test in which the reading of the thermometers in the oil and mercury wells was about 265° Fahr.,

for uniform conditions, the minimum temperature registered by the thermometer in the mercury well, after applying water to the pipe, was 232° Fahr., and for the thermometer in the oil well 244° Fahr. Similar figures for other tests were: Mercury well 219 degrees, oil well 236 degrees; and mercury well 221 degrees, oil well 239 degrees Fahr.

The thermometer in the oil well continued to indicate a decrease of temperature after the thermometer in the mercury well had attained the lowest temperature. The temperature registered by the thermometer in the oil well was considerably in excess of that registered by the thermometer in the mercury well at the time the minimum temperature was registered by the latter. For example, in the case of the tests just given, when the thermometer in the mercury well registered 232, 219 and 221 degrees, the thermometer in the oil well registered 255, 241 and 250 degrees Fahr.

The Bristol thermometer, with the bulb in direct contact with the superheated steam, was found to respond more quickly than a mercury thermometer placed in a well containing mercury, and to be practically of the same sensitiveness as a mercury thermometer placed in direct contact with the steam.

ERRORS IN MEASURING THE TEMPERATURE OF SUPERHEATED STEAM.

There may be a considerable error involved in measuring the temperature of superheated steam by means of mercury wells. For example, in work undertaken some time ago it was necessary to accurately measure the amount of superheating in steam at 80 pounds per square inch above the atmosphere, flowing through a 3-inch main at a velocity of 50 feet per second.* To do this, a 6-inch drum, about 1 foot long, was placed in the 3-inch main, and two mercury wells, 4 inches deep, were placed in this drum. One of the wells was made of $\frac{3}{8}$-inch standard pipe, as shown in Fig. 3, and the other was made with an enlarged bulb, as shown in Fig. 4. The mercury well with the enlarged bulb indicated a temperature about 4 degrees higher than the

* See paper on Results of Measurements to Test the Accuracy of Small Throttling Calorimeters. Transactions, A. S. M. E., Vol. XVI, page 451.

well of the ordinary form. This difference was not found in the case of saturated steam, and in other cases as great a difference has not been found with superheated steam. It is possible to have water running along the bottom, or clinging to the sides of a pipe, while the steam in the pipe is superheated. This was the case with the 3-inch pipe already mentioned, where, with the thermometers indicating 10 or 15 degrees of superheating, water could be drawn from a drip leading from the lower part of the 6-inch drum. The difference of 4 degrees in the results obtained with the two wells was obtained with about 30° Fahrenheit of superheating, and no water dripping from the drum. The pipe and drum were well covered with hair felt.

Another experiment to show how errors may occur in the measurement of temperatures of superheated steam, was made with the apparatus shown in Fig. 5. Three mercury wells were connected together so that steam passed around and downward past each in succession. Superheated steam at 65 pounds pressure per square inch above the atmosphere passed through the piping and around the mercury wells at the rate of about one pound per minute. The vertical nipples surrounding the mercury wells were of 1-inch standard pipe, and the horizontal nipples of half-inch standard pipe. In the first tests the mercury wells at A and C were of brass, of the form used by Mr. Barrus in his calorimeter, and the well B was of ¼-inch standard iron pipe. The brass wells at A and C were 4 inches long, projecting 3 inches into the steam space, and the iron well at B was about 3 inches long. The apparatus was thoroughly covered with hair felt. The steam was superheated in different tests from 5° to 20° Fahr. Readings were taken at intervals of 2½ minutes for an hour or more, after which the positions of the wells were interchanged and another set of readings taken. An iron well, 4 inches long, was also compared with the brass wells. Before starting to take the readings with superheated steam the indications of the thermometers were recorded with saturated steam, at 65 pounds pressure, flowing through the apparatus, and the increase of the readings of the thermometer gave the number of degrees of superheating. The tests with saturated steam were

also made after each set of readings with superheated steam. The tests showed that the thermometer in the 3-inch iron well at B indicated 3 degrees less superheating than when placed in a brass well at B, when the total amount of superheating as indicated by a thermometer in a brass mercury well at A was 8° Fahr. With 15 degrees superheating at A, the 3-inch iron well gave 2 degrees less superheating at B than the brass well at B.

The 4-inch iron well indicated 1 degree less superheating than the brass well when placed at A.

The results of these experiments are in line with numerous other observations which have been made for measuring the temperture of superheated steam.

The above discrepancies are not found in the case of saturated steam, as has been already explained.

DESCRIPTION OF EXPERIMENTS MADE AT MESSRS. YARROW & CO.'S WORKS, POPLAR, JANUARY, 1896.

(The following description and accompanying photographs were kindly supplied by Messrs. Yarrow & Co.)

With a view to throw light on the circulation of water in Water Tube Boilers, Messrs. Yarrow & Co. have carried out numerous experiments, and considering that the results obtained would be of interest to engineers at the present moment, they determined to make them public.

One point which these experiments prove is that the heating of down tubes actually accelerates the circulation and does not retard it, as is generally believed.

EXPERIMENT NO. 1. The cut represents the model used in these trials. It consists of two vertical glass tubes attached to the bottom of a small tank, the tubes being united at their lower extremities by a copper bend. There are six Bunsen burners, three acting on each tube, and arranged so that they can be regulated at will. On the upper part of the model is a balance, one arm of which is suitably loaded, and from the other arm is hung, by a thread, a grooved ebony bob, which is suspended in the down tube in such a manner that the water when flowing downwards, acting on the bob, causes it to descend, depressing the end of the balance to which it is attached. This experiment does not indicate the speed of the current, but it shows very clearly any increase or decrease in the speed of the descending column of water, that is to say, the rapidity of the circulation.

When the pointer is vertical, it is at zero; when it moves over towards the up tube side the figures are indicated as minus; when it moves towards the down tube side the figures are indicated as plus.

The following are the results of carefully tried experiments:

When no heat was applied, the pointer indicated —45; when only one lamp was acting on the up tube, the current was too intermittent to record a reliable result; when two lamps were acting on the up tube, the pointer indicated —12, as shown in the cut; when three lamps were acting on the up tube, the pointer indicated —5; when three lamps were acting on the up tube and one on the down tube, the pointer indicated +10; when three lamps were acting on the up tube and two on the down tube, the pointer indicated +15; when three lamps were acting on each side, the pointer indicated +20.

These experiments clearly prove that the circulation gradually increased as more and more heat was applied, irrespective of the proportion of the total heat observed by the up and by the down tube. Further experiments showed that, within certain limits, the rapidity of the circulation depended solely upon the total amount of heat applied, irrespective of how this heat was divided between the descending and ascending columns.

EXPERIMENT No. 2 is illustrsted by a similar model. In the down tube is placed a small screw propeller, which, when revolving, actuates a vertical spindle, having at its upper end a worm, gearing into a small worm wheel, as will be seen. This arrangement was made at the suggestion of Mr. Maxim, and it enables the speed of the current, under varying conditions, to be estimated.

When two lamps were acting on the up tube, the speed recorded by the propeller was found to be 28 feet per minute; when three lamps were acting on the up tube, the speed was 36 feet per minute; when three lamps were acting on the up tube and one on the down tube, the speed was found to be 42 feet per minute; when three lamps were acting on the up tube and two on the down tube, the speed was 49 feet per minute; when three lamps were acting on the up tube and three on the down tube, the speed was 55 feet per minute.

These experiments confirm those previously described with the suspended bob, proving a gradual increase of speed in the circulating system as more and more heat was applied, irrespective of whether this heat was absorbed by the water in the up

tube or by the water in the down tube. It should be remembered that, owing to the resistance offered to the flow of water by the screw, the actual speeds, if no screw had been there, would have been greater than those above recorded. In addition to this, an allowance must be made for the slip of the screw.

It must be borne in mind that in all the foregoing experiments circulation must have been set up by heat being first applied to the up current, which in all water tube boilers is the case, those tubes nearest the fire being heated first, and thus circulation is established.

These experiments also illustrated what has not yet, we believe, been referred to, viz., that any bubbles of steam formed in a descending column rapidly disappear; and it is more than probable that in a down tube moderately heated no steam whatever is formed, because as the current descends, the temperature of the water can rise without producing steam owing to the increased head of water and the higher temperature of the boiling point at the greater pressure. For example: under atmospheric pressure the water in the upper part of a tube would boil at 212°; but the water in the lower part of the tube, if 4 feet long, would boil at 218½°; consequently the whole body of water can be raised from 212° to 218½° while descending without producing any steam. This heat, thus absorbed, is given off by the conversion of a portion of the water into steam as the current ascends in the up tube. In the experiment the bubbles could be clearly seen forming where the flames impinged, and, as they descended, to disappear, the steam parting with its heat and raising the temperature of the surrounding water.

EXPERIMENT 3 was illustrated by a model consisting of two glass tubes, placed at a small angle to the horizontal, their upper ends being connected to a small cistern and their lower ends united. The tube on one side was arranged to be heated by three Bunsen flames and the other tube also by three Bunsen flames of smaller size. When once the circulation was started in the up tube by the three larger flames, those acting on the down tube could also be lit and the circulation could be clearly seen to be accelerated.

EXPERIMENT 4 consisted of a cistern from the bottom of which were led three tubes, the lower portions of which were of copper and the upper portions of glass. The three copper tubes were united at their lower extremities, being secured to a horizontal chamber. They were all situated in a gas furnace, lined with asbestos, heat being applied directly to the tube on the one side by means of several multiple Bunsen burners, the flames from which passed across the other two tubes and up the funnel which is seen in the photograph. This experiment more nearly approaches the conditions of an ordinary Yarrow Water Tube Boiler, and it was seen that sometimes there were two down currents in the two cooler tubes, and one up current in the tube most heated, and at other times there were two up tubes and one down tube. In this model as much as 9 pounds of water per square foot of heating surface was evaporated.

EXPERIMENT 5 consisted of two glass tubes projecting from a small tank, the tubes being nearly vertical. These glass tubes were united to copper tubes, at the bottom of these was a T-piece to which a third tube of copper was connected, the upper extremity of which was secured to the bottom of the tank. The two composite glass and copper tubes were in front and the copper tube was at the back, this latter representing an outside down pipe. Multiple Bunsen burners were provided for heating all three tubes. On heating the two front tubes an up current was established in both, the copper tube at the back serving as an outside down pipe, and the speed of the current could be seen by watching the flow of water and steam in the glass tubes. When heat was applied to the down comer at the back, it was clearly evident that the circulation was accelerated.

EXPERIMENT 6 consisted of a small tank from which were led two inclined glass tubes, united at their lower extremities. Provision was made to introduce a current of air from an air tank under pressure into either or both these tubes, as will be seen. When upward circulation had been established in the one tube, by introducing bubbles of air, then a further supply of air was admitted into the down tube, which air passed downwards with the water and then upwards in the up current, increasing the

circulation, which was maintained even after the supply of air had been completely cut off from the tube containing the ascending column, the circulation continuing in the same direction, air only being admitted into the down tube.

All the foregoing experiments were made at atmospheric pressure.

EXPERIMENT 7 showed the action under a pressure of 150 pounds per square inch. It will be seen that at the upper part of the model is a steam chest, to the bottom of which was attached a U tube, fitted with glass at its upper extremities, so as to render the circulation visible. There were three small Bunsen lamps in connection with the one leg, and five large Bunsen lamps in connection with the other leg. It was found that if the circulation was once established by lighting the three small Bunsen flames on the one side, producing an up current on that side, then the five large flames on the down current might be started, increasing the circulation, which actually continued after the three flames in the up tube were all turned out. This extreme condition under which circulation can be maintained, we venture to say, is one which few engineers would believe possible, and confirms the views expressed by Prof. Lambert and Mr. Maxim.

EXPERIMENT 8 was made on a full size section of a water tube boiler with straight tubes, working at a high pressure. At one end there was a furnace under forced draft by means of a jet in the funnel. The flame passed transversely across the group of tubes to the funnel, situated at the end opposite to the furnace. In the tube furthest removed from the furnace was placed a small screw propeller, and also a similar fitting in the third tube from the end, by which the direction of the current and its minimum speed could be estimated. On raising steam and forcing the fire the propellers were seen to revolve in a direction indicating a steady down current in either one or both of the tubes in which the propellers were introduced, previous experiments proving that a down current existed in the second tube from the end. It was found that there were never less than two down tubes in operation.

EXPERIMENT 9 represented also a full size section of a water tube boiler having straight tubes, heated in the same manner as in the former case. The circulation was rendered visible by the upper part of the tubes being of glass. It could be clearly seen that an upward current was established in those tubes nearest the fire, water descending in those which were furthest removed from it, confirming the previous experiment.

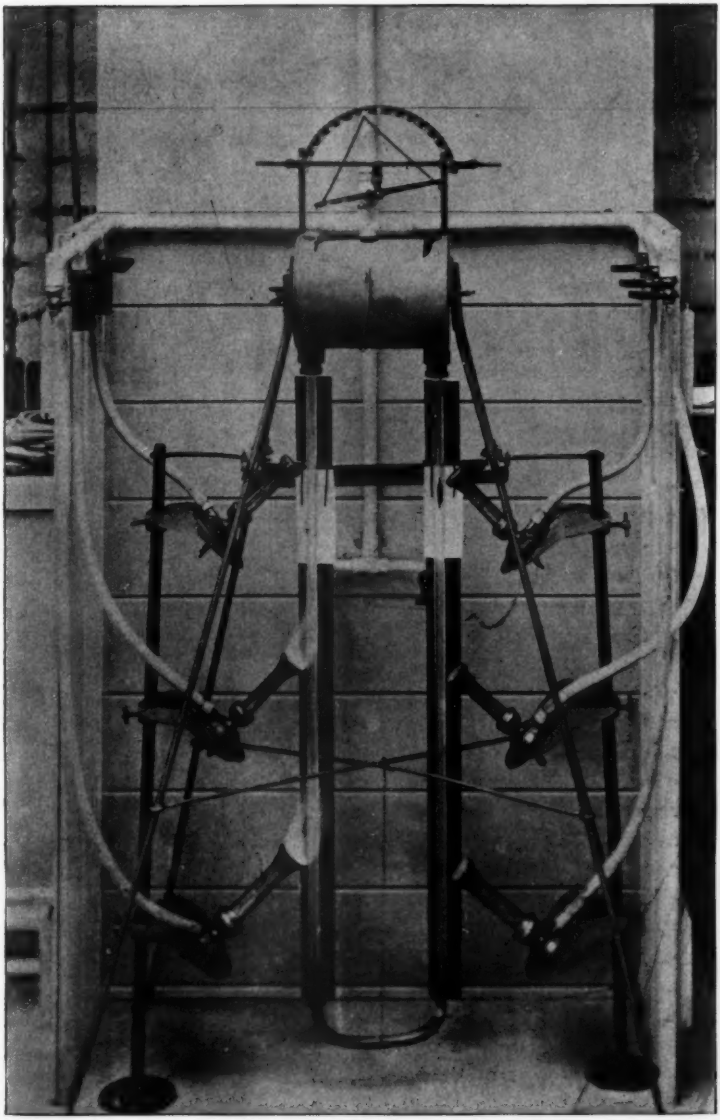
It may here be remarked that the maximum evaporation obtained by Messrs. Yarrow & Co., when the circulation has been forced to a very high pitch, was 25 pounds of water per square foot of heating surface, but, this being an uneconomical amount of forcing, is far beyond the range of what is desirable in practice.

Experiment No. 7 clearly proved that circulation was more efficiently maintained at a high than at a low pressure, it being found that the extreme condition of maintaining circulation by applying heat only to the down pipe was never certain, except with pressures over 50 pounds per square inch; between 30 pounds and 50 pounds this result was doubtful, and below 30 pounds it was not possible.

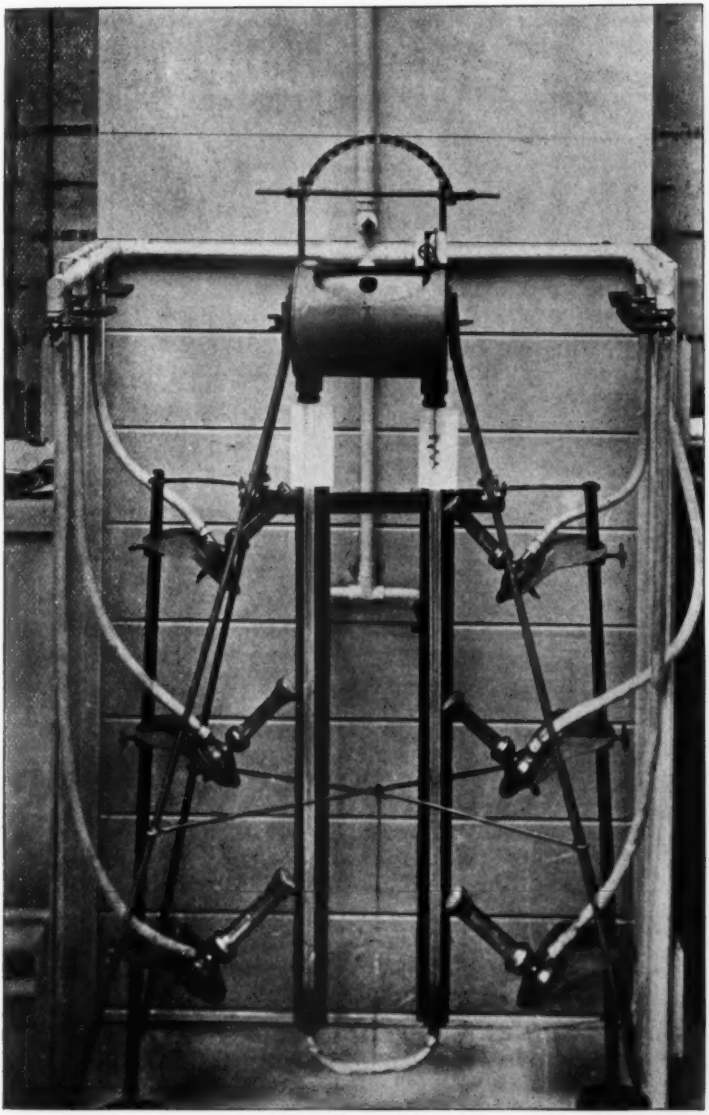
The reason of this is probably due to the reduced velocity of of the down current in the case of low pressure, owing to the greater bulk of a given weight of steam at low than at high pressures, all of which steam has to pass through the up tube, or in other words, there is less resistance to a given weight of water and steam at a high pressure flowing through a system of tubes than at a low pressure, on account of the lesser bulk of the water and steam in the former case.

The exact arrangement of the propellers in connection with No. 8 experiment is clearly seen by the sketch showing a section through the steam chest and one of the tubes containing the propellers.

In order to obtain reliable data as regards the temperature of the tubes, which are exposed to the fiercest action of the fire, the following facts in connection with No. 8 experiment will be instructive, and to fully explain, reference must be made to the section through the tube nearest the fire.



EXPERIMENT No. 1.



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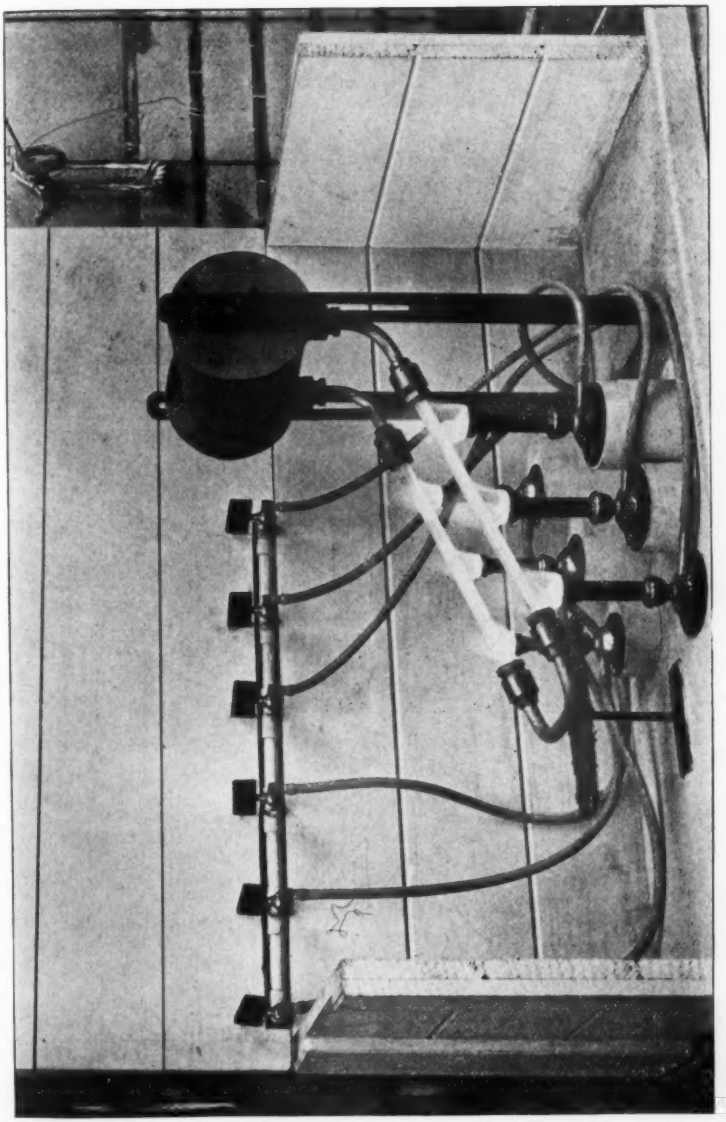
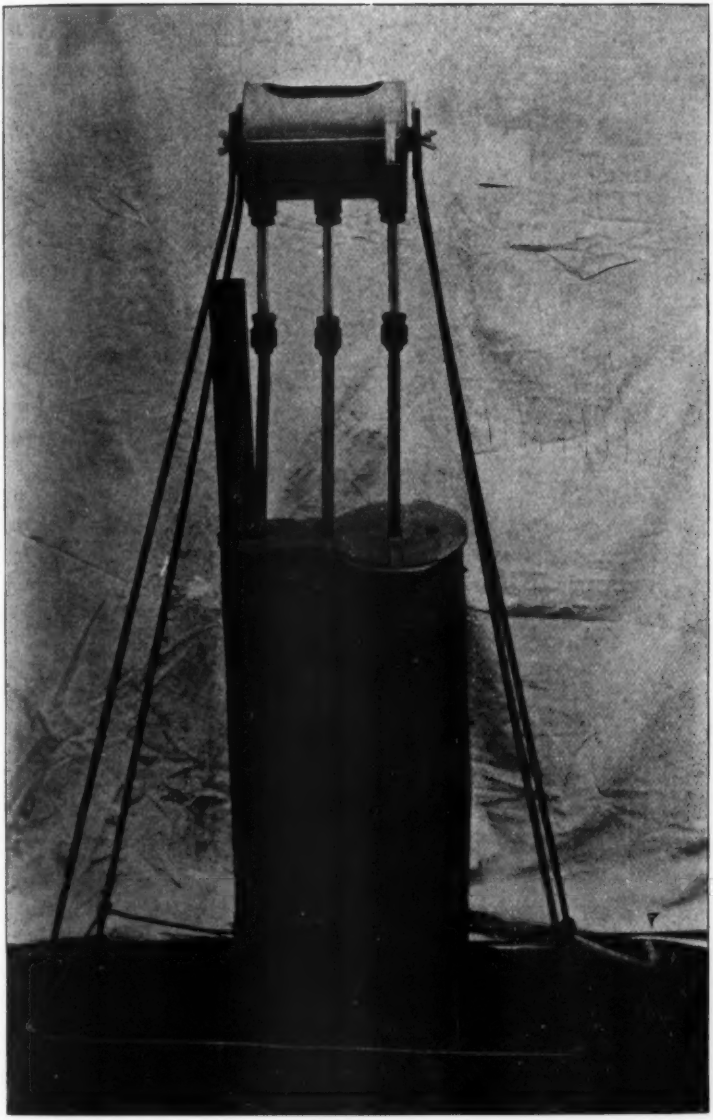
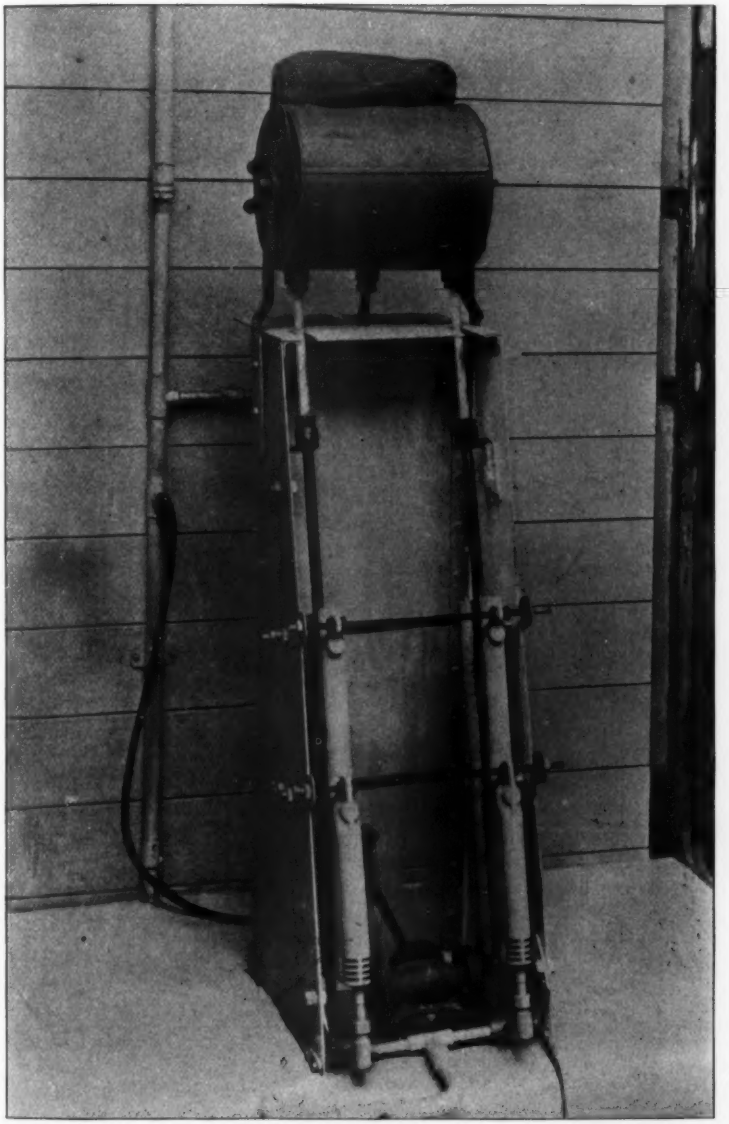


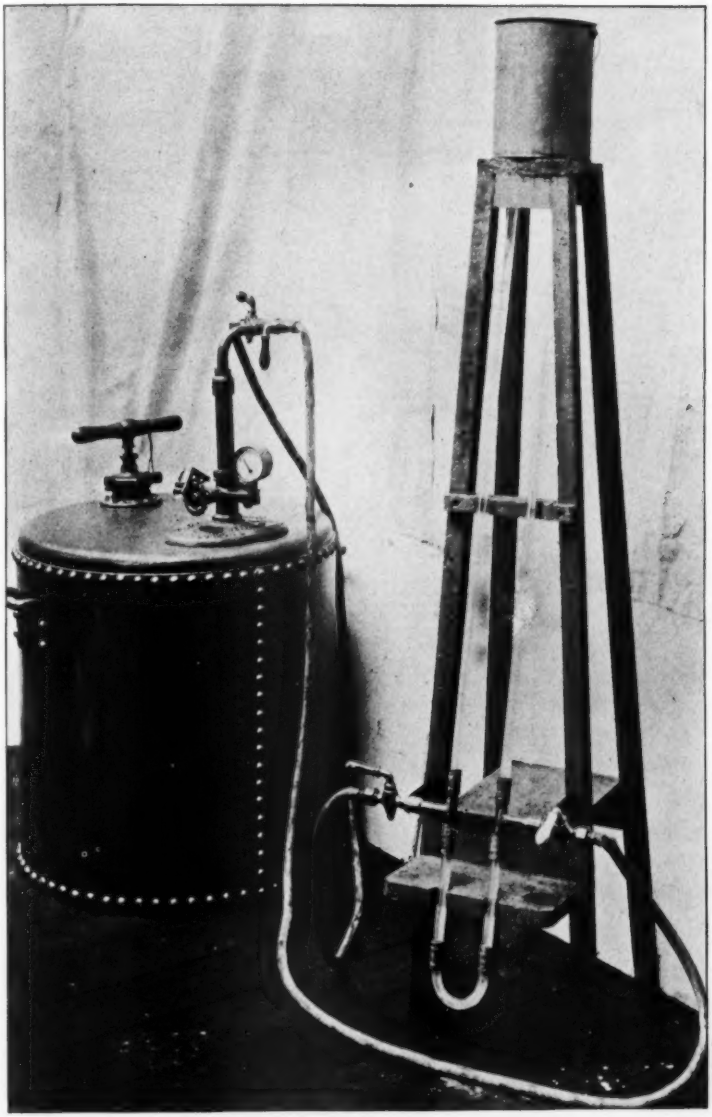
EXPERIMENT No. 3.



EXPERIMENT No. 4.



EXPERIMENT NO. 5.



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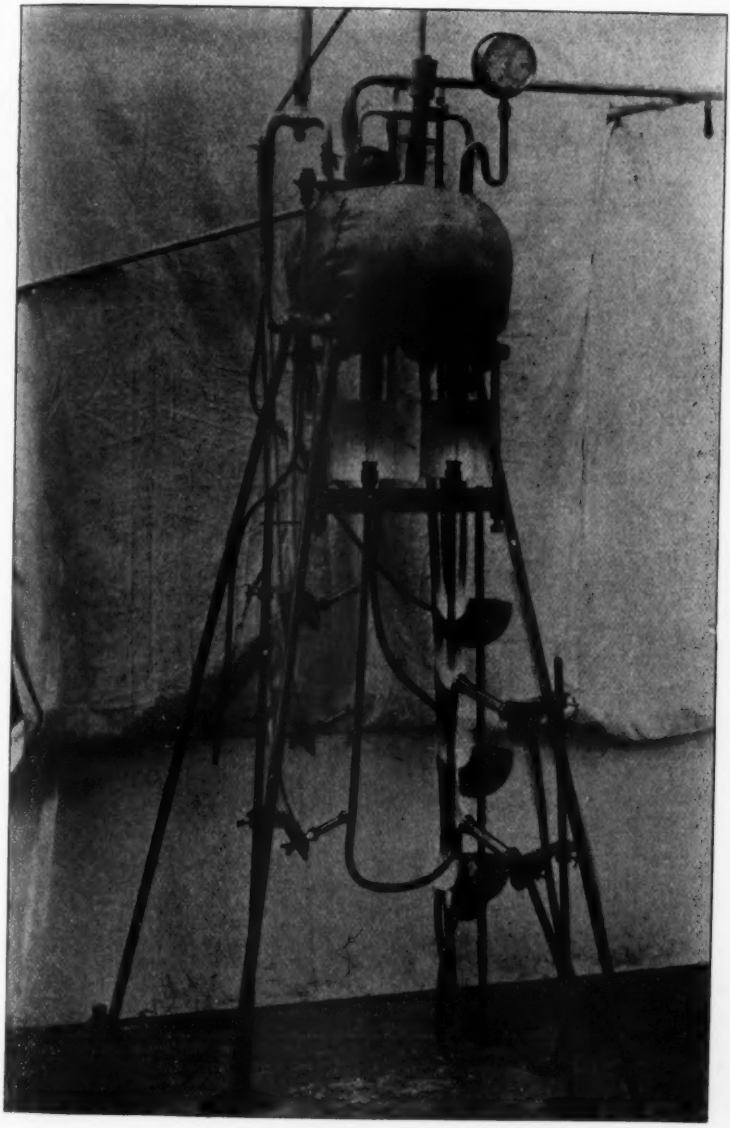
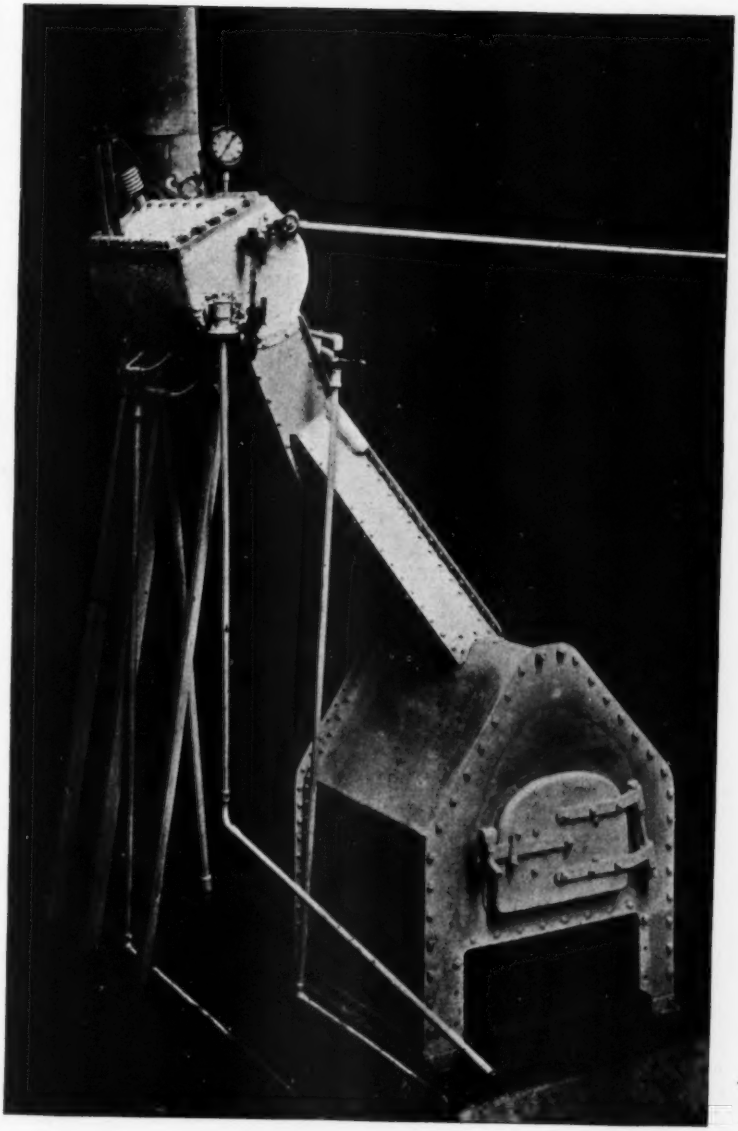
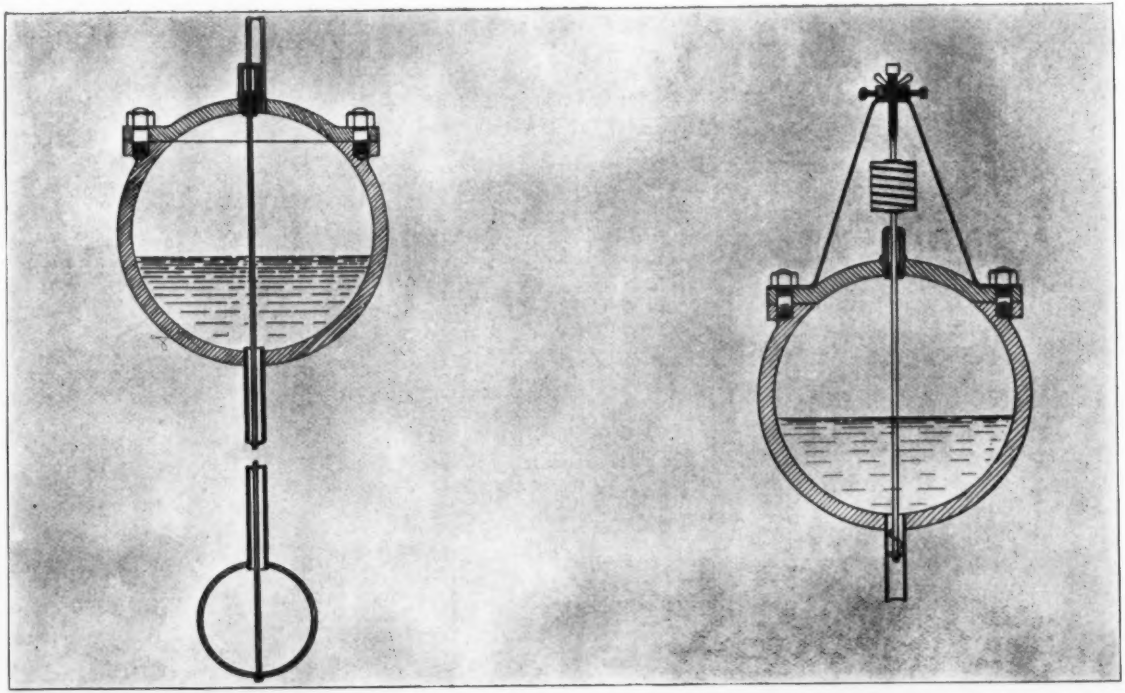


EXPERIMENT No. 7.



EXPERIMENT No. 8.

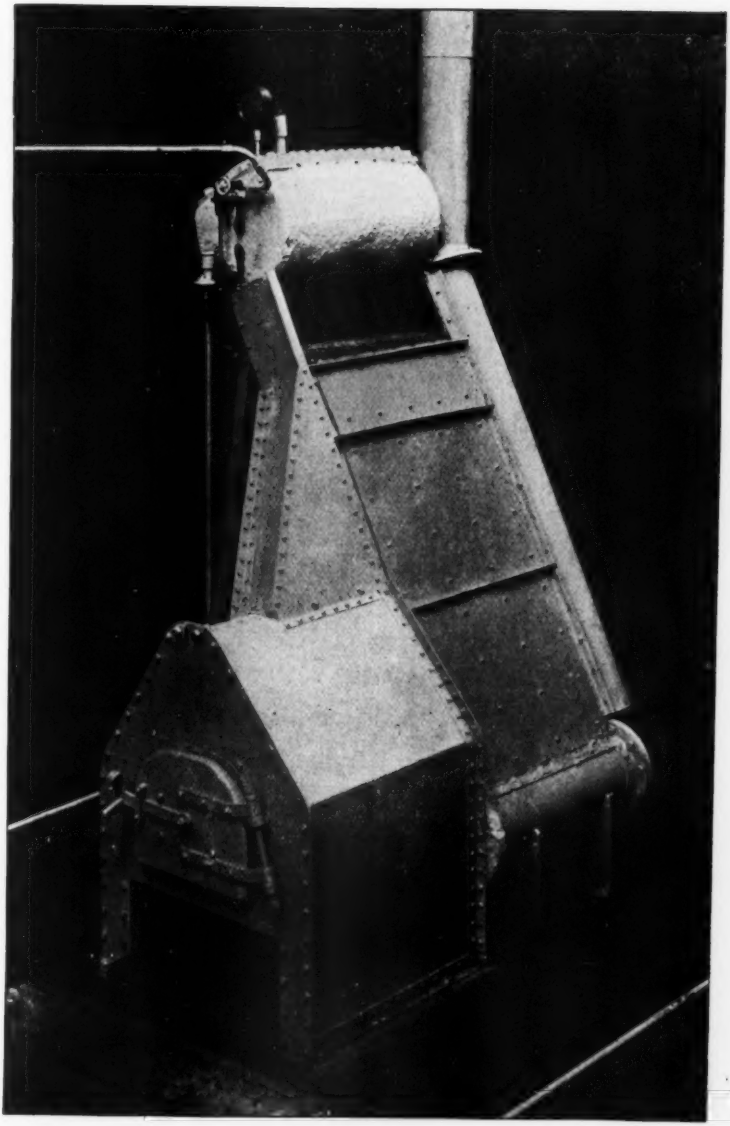


EXPERIMENT No. 8.

SECTION THROUGH BOILER AT THE TUBE NEAREST THE FIRE.

EXPERIMENT No. 8.

SECTION THROUGH STEAM CHAMBER WHERE THE SMALL PROPELLERS ARE FITTED IN THE TUBES.



EXPERIMENT No. 9.

The lower end of a long rod was attached to the water chamber at the bottom, this rod passing up through the center of the tube and thence through the top of the steam chest. At the upper end of this rod was a pointer and a similar pointer was fixed to the steam chest itself as will be seen, the two pointers being exactly in a line with one another. Thus whatever difference in the relative lengths of the tube and the rod took place, it would be at once made evident by alterations in the position of the pointers in relation to one another. If thus the tube, owing to its being exposed to great heat, expanded more than the rod, it could at once be detected and any such increased relative length would be an indication of an increased relative temperature.

Now it was found that there was no visible difference in position between the two pointers, whether the fire was forced or extinguished, and as the rod passing up through the steam and water would have a temperature equal to that of the steam and water, it follows that the temperature of the tube is the same, or the difference, if any, is so trifling as not to be indicated by the means above described.

This experiment conclusively proves that, so long as there is good circulation, no possible objection can exist to the adoption of straight tubes, as in a Yarrow Boiler, owing to any imagined necessity to allow for variations in length, due to differences of temperature. For all practical purposes, the temperature of all the tubes may be considered the same as that of the water they contain, in the same manner as in an ordinary marine or locomotive boiler, in which no special provision is made for differences in expansion of the tubes, although they are by no means all exposed to the same extent to the action of the heated gases. This experiment, which is confirmed by practical experience in the use of the Yarrow Boiler, points conclusively to the fact that the curving of tubes in water tube boilers (having good circulation), for the sake of allowing for variations in length due to variation of temperature, is quite unnecessary.

ON "COMPARISON OF MECHANICAL DRAFTS."

By Mr. John Thom, M. I. N. A.

[Read before the Institution of Engineers and Shipbuilders in Scotland, and reprinted from the "Engineers' Gazette," London.]

When I promised the Secretary to read a paper this session I intended the subject to be "Water Tube Boilers." From unforeseen circumstances, however, it is not advisable for me at present to give the results of experiments made by me.

Instead, I have written a short paper, sufficient to start a discussion, on "Mechanical Draft," being led to choose this subject through having crossed the Atlantic three times in an official capacity, and each time in a vessel fitted with a different arrangement of mechanical draft.

My intention is to mention the results obtained from the arrangements adopted in these vessels and other systems that have come under my own supervision, and it will be instructive if other members will give their experience with any other arrangements.

The systems I took notes from were:

First. The closed stoke hole, usual Admiralty system, gratings covered over and air forced into the stoke hole with fans and air locks for allowing men to enter and go out.

Second. The well-known Howden system of forced draft, with the air heated on the way to the furnaces by the hot gases as they pass to the funnel.

Third. The Ellis and Eaves arrangement of induced draft, with the air heated on the way to the furnaces, similar to Howden's system, but the fans in this instance are placed at the base of the funnel and induce the gases to them (will be spoken of as suction draft in this paper).

Fourth. The closed ash pit arrangement, with fans discharging direct to the furnaces, and stoke hole gratings open.

A. The first arrangement mentioned, the closed stoke hole, is still working satisfactorily after many years' use, and does not appear to injure the boilers as it is worked. The air pressure carried is $\frac{3}{4}$ inch in the stoke hole, burning 25.9 pounds of coal per square foot of grate, and giving 16.1 I.H.P. per square foot of grate and .372 I.H.P. per square foot of heating surface.

The result of a good passage with very good American coal was 1.6 pounds of coal per I.H.P. per hour; with American coal the full power developed is only about 5 per cent. less than the Welsh coal.

This system is very simple, although the air locks are inconvenient and all the bunkers require to be air tight, as the air would escape from the stoke hole through them, as the bunker doors must always be left open (if there is any leakage the coal dust will be blown on deck). The inconvenience of air locks is not so much felt in a large steamer, where the engineer remains a full watch in the stoke hole. The stoke hole is very dirty, especially with Welsh coal. The temperature of the stoke hole was 116° Fahrenheit, with the atmosphere at 62° Fahrenheit mean of voyage.

B. Howden's, the second system, fitted in a sister vessel to the first, is a decided advantage in many respects. The stoke hole can be left open to the engine room and is much cleaner; there is not so much dust flying about. Care must be taken to make the uptakes and casings air tight, or the arrangement is not so effective, as the gases escape into the stoke hole. This arrangement is worked with a shorter fire bar and burning a greater quantity of coal per square foot of grate, owing to being able to carry a higher pressure at fires through having valves for shutting off the draft while firing.

Of course there are more complications on the boiler front which require attention, but there is an average saving of about 8 per cent. in the coal bill over the first system, due to the heated air and retarders.

This arrangement is not so suitable for American coal as it is for Welsh coal. The falling off in full power, due to using American coal instead of Welsh, is about twice as much as it is in the

vessel with the closed stoke hole. The temperature of the stoke hole is about the same as it is with the closed stoke hole system—116 degrees, with the atmosphere at 61 degrees. Taking the results from a good voyage with Welsh coal, with $3\frac{3}{4}$ inches air pressure at the fans, and $1\frac{1}{4}$ inches at the ash pits, burning 28.2 pounds of coal per square foot of grate, that is with 18.6 I.H.P. per square foot of grate surface and .393 I.H.P. per square foot heating surface, the consumption is 1.52 pounds of good Welsh coal per I.H.P. per hour.

C gives the results from a more recent arrangement of Howden's system on trial. When indicating on trial 24.13 horse power per square foot of bar surface and .577 per square foot of heating surface, the temperature of the funnel gases was 496 degrees and air entering fires at 159 degrees, and $3\frac{1}{8}$-inch W.G. pressure of air at fans, the heating surface of air heating tubes equal about one-third heating surface of boiler.

D. The Ellis and Eaves arrangement is the latest system of mechanical draft, and has been developed at Messrs. John Brown and Co.'s, Sheffield, where they have a large number of boilers working under this system.

This combination of Howden's and Martin's systems with Serve tubes makes a comfortable arrangement. The stoke hole is open as with ordinary draft—in fact it is just ordinary draft intensified by the fans—the air before reaching the furnaces is drawn through horizontal air heating tubes, the hot gases on their way to the funnel pass round outside these tubes so that the air is heated, as in Howden's arrangement on voyage mentioned, to 308 degrees Fahrenheit, the air drawn from above the boilers entering the air tubes at 117 degrees and at fan delivery or funnel base 395 degrees. The heating surface of air heating tubes was about the same as total heating surface of main boiler, or three times greater in proportion than Howden's arrangement. There is, however, this advantage, the furnaces are under less pressure than the stoke hole, and a certain quantity of cold air can be allowed to enter from the stoke hole below the fire bars; this sweetens the air in the stoke hole, as the air that is taken away is replaced by pure air from above, and any leak-

ages about the furnace fronts or casings act in the same way, drawing in air. The temperature of the stoke hole was only 80 degrees.

A certain amount of cold air admitted under the fires does not appear to affect the economy much. When cold air is admitted in this manner there is less heated air drawn through the tubes, but the hot air which is drawn through them will be of higher temperature through having been longer in the tubes. The cold air admitted below the bars should help to keep them cool.

From experiments made at Sheffield, it was discovered that by raising the fire bars a few inches at the back (instead of lowering them at the back in the usual way) the bars would allow the fires to be forced very much more severely, and would give no trouble when burning over 60 pounds of coal per square foot of grate. Sloping the bars up towards the back has a further advantage, that it is easier to see that the whole of the grate is covered through the fire door, and there is no chance of the flame being blown in your face. Another advantage the arrangement in this vessel possessed was the control the engineer had of regulating the quantity of heated air admitted above and below the bars, with peep holes to watch the result while regulating. With bituminous coal all the hot air would be put over the fires and the smoke almost entirely consumed.

The consumption per I.H.P. (on voyage) of which particulars are given, was 1.41 pounds per hour with soft coal (not South Wales coal), that equals .539 I.H.P. per square foot of heating surface, and 17.13 I.H.P. per square foot of bar surface, and 24.2 pounds of coal per square foot of grate, with 3¼ inch W.G. vacuum at fan and chimney, and 1 inch W.G. vacuum at ash pit.

I should mention that in firing and cleaning fires, the action of opening the door automatically closed off the draft from the furnace and prevented the cold air from rushing in. At Sheffield they think this an unnecessary precaution, and I do not think it is adopted there. They hold the opinion that with suction draft the heat impinging on the ends of the tubes and tube plates is altogether different to what it is with forced draft. The adherents of suction draft say it sweeps clear of the ends of

the tubes and enters in the center, while with forced it impinges on the tube ends. Many other engineers maintain that the action is precisely the same in each case; the draft is due to the difference of pressure at the base of the funnel and at the furnace mouth. This is a point that should be noticed in the discussion; each speaker should give his opinion whether he believes suction and forced draft synonymous terms or not; if speakers are diffident, we should take a show of hands, as the discussion on Mr. Martin's paper before the Institute of Naval Architects still left the point disputed.

From experience at Sheffield, from the same reason as given for saving tube ends, they advise the air space at the back of furnace between the bars to be reduced, as the draft is more intense at the back end of grate.

The fans are about double the capacity in the suction arrangement of draft compared with the other arragements, due to the gases having expanded by the heat, and the gas from the coal burned having to pass through the fans.

Although double the capacity, the adherents of suction draft maintain the fans do not require double the power, as the work done is much the same, whether you put the power at either end of the conduits, but the fans, being larger and heavier, have more friction, and are said to require 25 per cent. more power to work them in handling the lighter gases.

With suction draft it is quite possible where the fans draw from a common conduit to have much more fan power than necessary. In that case it may be found in some instances that one fan will not be doing any useful work, merely keeping the air from going back through it, but not discharging any gases, the other fan being capable of doing all the work required.

The air heating tubes in this arrangement reduce the temperature of the gases to a point that can easily be handled by the fans.

The bearings of the fan next the casing is kept cool by circulating water round the bottom bearing. These bearings should be made very long to prevent the fans wearing down; this refers to all fans. Good fans have the end bearings next the fans over three diameters in length.

E. The closed ash pit system is the fourth arrangement mentioned. Although perhaps the oldest, this is the least adopted, through the fear of using cold air under a high pressure. The arrangement works very well if properly designed. You can get a very high power from a light boiler, but you must take the precaution not to inject the air directly into the ashpit, only arrange it so that the air is circulating all over the furnace front, and let pressure into the furnace at various parts above and below the bars. The stoke hole is quite open in this system, and it has this advantage over all the others, that you have merely to open the ashpit doors and stop the fans in order to work with natural draft. The fans draw from the engine room or stoke hole, as desired, and keep the engine room and stoke hole more comfortable than with natural draft. You will notice from the table that with this arrangement the power on trial was very high for the weight and heating surface—22.6 I.H.P per square foot of bar surface and .714 I.H.P. per square foot of heating surface, with 4 inches air pressure at fans and 2 inches at ashpits.

Under ordinary cruising conditions the power was reduced to 13.3 pounds of coal per square foot of bar surface, and .418 I.H.P. per square foot of heating surface. The consumption was 1.56 pounds of Welsh coal per I.H.P. per hour, with $1\frac{3}{4}$ inches air pressure at fans. This arrangement has also been working satisfactorily for years.

The results given are from a similar arrangement to that so well worked out by Mr. D. J. Dunlop, Port Glasgow, and published in "Engineering," March 18, 1892, fitted in the yacht *Mira* which had the exciting race from Cloch round the Cumbræs with the yacht *Hermione*. This was a private tussel—closed ashpit *versus* Howden—and ended in a victory for the closed ashpit by several minutes. Both yachts were designed by the same naval architect.

For marine work (with the Ellis and Eaves' combination) I think it would be advisable to draw the air through outside the tubes, and let the coal gases pass through the tubes; they could then be swept when overhauling in port from outside the heating box, same as boiler tubes.

COMPARISON OF MECHANICAL DRAFTS.

	A Closed stoke hole system.	B Howden's system.	C Howden's system.	D Suction system.	E Closed ash pit system.	F Natural draft system.
Engines and working pressure	Triple, 160 pounds.	Triple, 160 pounds.	Triple, 180 pounds.	Quadruple, 200 pounds.	Triple, 170 pounds	Triple, 165 pounds.
I.P.H. per square foot of grate, trial	.....	.....	24.13	21.7	22 66	14.73
voyage	16.1	18.6	16.96	17.13	13.3	10
I.P.H. per square foot of heating surface, trial	.....	.....	.577	.682	.714	.5
voyage	.372	.393	.405	.539	.418	.346
I.H.P. per ton of boiler and appurtenances, trial	.....	.....	16 8	14.7	19.6	15.9
voyage	13.71	13.71	11.8	11 6	11.51	11
Length of fire bars	6 feet.	5 ft. 3 ins.	5 ft. 3 ins.	5 ft. 9 ins.	6 ft.	5 ft. 6 ins.
Pounds coal per square foot of grate, voyage	25.9	28.2	25.3	24.2	20.7	15.4
Pounds coal per I H.P. at time cards were taken	.....	.....	1.4	.....	.....	.....
Pounds coal per I.H P. per hour, mean of voyage	1.6	1.52	1.54	1.41	1 56	1.53
Quality and purpose used for	American, very good, used for propelling machinery only.	Welsh, good, used for propelling machinery only.	Soft coal, used in main boilers for all ship's purposes.	Soft coal, used in main boilers for all ship's purposes.	Welsh, used in main boilers for all ship's purposes.	Soft coal, used in main boilers for all ship's purposes.

In further reference to the table of comparisons annexed, the first two refer to mail steamers kept continually working at full power. They are exactly the same in every respect, except the system of draft employed.

These two steamers when working under favorable conditions, the closed stoke hole made the fastest passages with American coal and the Howden system the quickest with Welsh coal; but latterly the closed stoke hole is quicker, taking all last season on an average, of six hours per passage. This vessel was not designed to suit Howden draft originally, but the boilers were designed to suit forced draft. The average consumption of average voyages with Welsh and American coal takes 10 per cent. more coal per I.H.P. than mentioned in table.

The furnaces with the closed stoke hole arrangement stood quite as well as with Howden's draft, but the tubes began to leak at combustion chamber end, and her boilers had to be retubed at a much earlier date than with Howden's draft.

Altogether, it is a very creditable result for the Admiralty system where you can afford to carry weight for engines large enough for economical working with a good number of expansions.

The I.H.P. per ton of boilers and machinery is almost as great in these two express vessels on ordinary work as the others on trial. This is where the human element comes in. The I.H.P. per ton of machinery is very nearly alike in the other examples.

The second two refer to swift cargo steamers of the same type.

The fifth column refers to a yacht of 1,500 I.H.P., showing that a large H.P. can be obtained with this arrangement when necessary. With it natural draft can be adopted, and save the decks from the discharge of ashes caused by forced draft. This trouble is common to all forced draft arrangements when used to excess.

Generally, I have no doubt that examples might be obtained from any of these systems, showing a greater power obtained from the coal or from the weight, but the examples I have taken are from vessels under or about the same conditions for a fair comparison.

On trial, in the instances mentioned, the closed ash pit arrangement is much superior to all the others in I.H.P. per ton of machinery, and Ellis and Eaves' system show the most power per square foot of heating surface on voyage. This should be expected, as it is the only one fitted with Serve tubes, but I do not think the full advantage of these tubes has yet been taken in designing boilers. I have advised in boilers now building to reduce the number of tubes. In that way we get larger furnaces, and greater power from the same dimensions of boiler, and depend on the heat absorbing power of the Serve tube to make the heat distributing furnace more effective. The Serve tubes will be worth paying for under these conditions. Howden's arrangement shows the greatest power per square foot of grate both at trial and on voyage, due to using shorter fire bars.

From my own experience I know that each of the systems can be made to work very satisfactorily. The furnaces will not give trouble with any of these systems so long as the air is properly admitted, although, naturally, one would be led to suppose that the heated air would do the furnaces less damage.

The closed ash pit becomes similar to the closed stoke hole system if in the closed ash pit system the air is kept circulating round the front, and is admitted by holes above and below the bars, as mentioned before, with this advantage in favor of the closed ash pit, that when working with high air pressure the blast is shut off while firing.

If necessary, with either of these arrangements the opening of the fire door can be arranged to automatically close off the fan from the draft in the one case or to the funnel in the other. This would certainly increase the life of the tubes.

The tables show that the most economical arrangements are the heaviest, probably because of the air heating tubes which are employed in these systems.

When the length of voyage is limited it becomes questionable whether the increased economy is worth obtaining when it is necessarily accompanied by increased weight. But in the case of a long voyage the smaller consumption will necessitate less

coal to be carried, and so the total weight of boilers and coal will be less than when lighter systems are employed.

The fans themselves are the most important factor of any forced draft system. When the fans are too small they have to be overdriven, and soon come to grief. I have found that a good empirical rule for the capacity of the fan is—

$$\frac{\text{Width at periphery} \times \text{dia.} \times \text{cir., all in feet}}{3} = \text{cub. ft. of air per rev.}$$

Allow for 250 cubic feet of air per pound of coal to allow for leakages, etc. Of course you will require to see that the speed of the fan periphery is suitable for the amount of air pressure to be carried, say—

$$8\sqrt{68 \times \text{inches water gauge air pressure}}$$

= speed of fan tips in feet per second to balance inches water; multiply by 60 and divide by circumference of fan in feet = revolutions of fan per minute for forced draft.

If you leave the proportioning of the fans to the fan-makers they are apt to supply fans which are much too small for the work required, in order to reduce the price.

If the fans are over double the capacity given by this rule they can be depended on to work in the funnel gases after they have been reduced in temperature by the air heating tubes.

These air heating tubes have been the saving of the induced system. When the fans are put direct in the funnel, as originally fitted, it is quite probable that you might find only the stumps of the blades left after the trial when consuming a large amount of coal with small heating surface.

Another decided improvement was that adopted by Messrs. J. and G. Thomson in the vessel from which the particulars are given, namely, in placing the fans on brackets on the casing of the vessel instead of on the hot uptakes, which soon heat up the fan base.

I should mention that all the arrangements mentioned are now fitted with retarders except the natural draft example. This seems to be an important factor in the economy derived from forced draft.

Some owners think it a greater invention than that of the

triple-expansion engines, because fitting it to some of their steamers when the conditions were favorable, the saving was as much as 10 per cent. of coal.

I should mention the consumption of coal per I.H.P. is arrived at by reducing the I.H.P. calculated from the diagrams at the revolutions the engines were then working, to the power equal to the mean revolutions from the counters on the voyage as the cube of the revolutions and the total coal consumed between ports, according to the American navy practice.

I am sorry the particulars of log for column C were not to hand to correct these particulars before the table was exhibited on the wall. The consumption should be 1.54 pounds instead of 1.4 per I.H.P. per hour, as originally stated. This shows the importance of taking the mean in this way. I am afraid the more accurate method will not be adopted by the superintendents here, as the report to the directors would immediately take a decided increase in consumption per I.H.P. per hour.

A friend proposed to add the particulars from a good modern ordinary draft steamer to the table for comparison at **F**; this I have done. All the steamers have the same style of feed heater except **E**, which is not fitted with one.

NOTES.

BELLEVILLE BOILERS.

(From "Engineering," London.)

The Belleville Boiler Company, of St. Denis, near Paris, has entirely abstained from taking any part in the very animated discussion on their system of generators, which has appeared in our columns for several months past. It seems somewhat to be regretted that the Company has refrained from publishing information which it must possess, and which would add greatly to the value and interest of the discussion. As, however, the company prefers to remain silent, it gives us all the greater satisfaction to be able to reproduce a report recently prepared by the engineers of the Compagnie des Messageries Maritimes, who are extensive users of the Belleville system. This report, based on data extending over a long period, was prepared at the request of the Messageries Company's directors, and deals with only one point of interest—coal consumption, as compared with that of cylindrical boilers. The information on this subject will be found of special interest in connection with the report of Mr. Robison, (see page 365, Vol. vii, of the JOURNAL)

"REPORT ON THE BELLEVILLE AND CYLINDRICAL BOILERS IN SERVICE ON THE MAIL STEAMERS OF THE MESSAGERIES MARITIMES COMPANY.

"In 1885 the Compagnie des Messageries Maritimes found it desirable to place new boilers on one of their ships, the *Ortégal*, and they decided to replace the return-flue cylindrical boilers that had been previously in service with the Belleville generator. This was the first experience of the company with this type of boiler. It appeared to the engineers of the company that the Belleville boiler possessed some very marked advantages over the older systems; they considered that it was evidently much

more elastic, that the design provided more freely for expansion and contraction, that firing would be easier and require less skill, that higher steam pressures than were safely available in cylindrical boilers could be maintained, and that the fact of their being made up of a large number of relatively light parts, rendered repairs easy during a voyage. Moreover, it was considered that the small volume of water they contained reduced their total weight, and diminished considerably the risk of serious accident to firemen in the event of a rupture or explosion taking place. On the other hand, it was recognized as a probable source of trouble and possible danger that the small water capacity of the generator would cause difficulty in maintaining the feed, and that accidents from this cause, though less dangerous, might be more frequent than with boilers of the cylindrical type. Experience has shown this fear to be without foundation.

"As regards the economy of the Belleville boilers, the engineers of the Messageries Maritimes arrived *à priori* at the conclusion that it would be inferior to that of cylindrical boilers in which the changes in direction of the products of combustion and the greater area of surface bathed by the heated gases, facilitate the transmission of heat and the more complete cooling of the gases. The circulation of the latter in the Belleville boiler was evidently inferior to that in the cylindrical boiler. It will be seen at the end of this report that an improved water circulation largely compensates for any deficiency due to the above-mentioned cause; but in the early days of first experience, the advantages due to this could not be discounted.

"Thus doubtful of the result, the Compagnie des Messageries Maritimes awaited the experience to be given by the new boilers of the *Orégal* before extending the application of the Belleville system in their fleet. The delay, however, was brief; the *Sindh* was fitted with these generators in 1887, but cylindrical boilers were placed on the *Brésil* and the *La Plata* in 1888. The results, however, obtained with the Belleville generators were so excellent as regards ease of management and repairs and economy in fuel, that the company in 1890 decided on adopting the system on the following ships of its fleet: the *Australien*,

Polynêsien, *Armand-Bêhic*, *Ville de la Ciotat*, *Ernest-Simons*, *Chile* and *Cordillère*, the last named being now fitted.

"The system has, therefore, been long enough in service and on a sufficiently large scale to enable the engineers of the company to ascertain with accuracy its present economic value. It is interesting, from this point of view, to compare the consumption of coal per horse power in two sets of similar engines, working under the same conditions as regards expansion, but one of which obtained its steam supply from a cylindrical boiler and the other from a Belleville generator. Such a comparative illustration is supplied by the engines of the *Brésil* and the *La Plata*, and the *Australien* and *Polynêsien*, respectively. All four engines are triple-expansion and develop practically the same horse power. The steam pressure at the slide valves of the two former was 128 pounds per square inch, and of the two latter, 156.45 pounds; the coefficient of expansion in working all four engines was similar, 11.8. The following was the method of investigation.

"The consumption of coal for each of the four ships was carefully recorded during the last half of 1894. That is, the consumption due to the main engines alone, deduction being made of the coal required for lighting, banking fires when in harbor, and for working auxiliary machinery, such as winches, dynamos, refrigerating machine, hoists, &c. The number of hours run, and the engine speed being known, the consumption of fuel per horse power could be deduced. As the mail steamers under consideration are supplied with different qualities of coal, in order to render the results correctly comparable, the gross figures obtained were reduced to what they would have been if standard Cardiff coal had been burned throughout. The power developed was calculated from the mean revolutions, and the mean speeds realized by two independent and differing methods, which gave similar results. The ratio of the power developed by the group *Australien* and *Polynêsien* on the one hand, and of the group *Brêsil* and *La Plata* on the other, proved to correspond exactly by the two methods of calculation. As what is most important in this comparative investigation, is the determination of these ratios of power, rather than their absolute values, it may be stated

that the coal consumptions per horse power per hour, given below, are accurate.

"1. The *Australien* and *Polynésien*.—During the second half of 1894, these two steamers made three voyages from Australia. The total number of hours of effective running was, for all three voyages and both ships, 9,255 hours 30 minutes. The average number of revolutions per minute, for the whole of this time, was 67.46. The mean power developed corresponding to the mean speed of the two ships, was 4,553 horse power, including 100 horse power for the circulating pumps.

"On the other hand, the total consumption of coal for the main engines and the accessory services for the two ships was 14,826 tons of Cardiff coal, 9,771 tons of Grand' Combe briquettes, and 17,863 tons of Australian coal. To reduce this consumption to what it would have been if Cardiff coal only had been used, it is necessary to multiply the weight of briquettes by .90, and that of the Australian coal by .80. The total quantity of fuel consumed is thus equal to 37,910 tons of Cardiff coal. The deductions to be made on account of the accessory services were ascertained by careful records kept throughout the periods of trial, and proved to be 7.4 per cent. The net quantity of coal consumed by the main engines was, therefore, 35,104.6 tons, or 8,342 pounds per hour, equivalent to 1.833 pounds per horse power per hour.

"2. The *Brésil* and *La Plata*.—The total number of effective running hours for the *Brésil* and *La Plata* during the same period of 1894 was 6,768.75 hours. The mean number of revolutions was 68.11; the corresponding average power was 4,010 horse power, including 80 horse power for the circulating pumps. The total consumption of coal for the main engines was 22,952 tons, corresponding to 7,475 pounds per hour, and to 1.863 pounds per horse power per hour. As these two vessels burnt only Cardiff coal no corrections had to be made on this account.

"It follows from the foregoing results that the *Australien* and the *Polynésien*, fitted with Belleville boilers, burnt 1.833 pounds of Cardiff coal per horse power per hour, and that the *La Plata* and *Brésil*, fitted with cylindrical boilers, burnt 1.863 pounds of Cardiff coal per horse power per hour. It may be

concluded, therefore, that the slight economy obtained by the *Polynésien* and the *Australien* was due to the slightly higher pressure than that of the other two vessels, and that practically the Belleville boilers have shown themselves in service as economical as the cylindrical boilers.

"It is especially to be noticed that the figures given above, and the results which have been deduced from them, refer to a long period of actual navigation, and therefore can in no way be compared with tests conducted for a period of a few hours; they are, in fact, practical experiments extending over several thousand hours.

"(Signed) RISBEC,
Director of the Works of the
Compagnie des Messageries Maritimes.

"LA CIOTAT, *December 20, 1895.*"

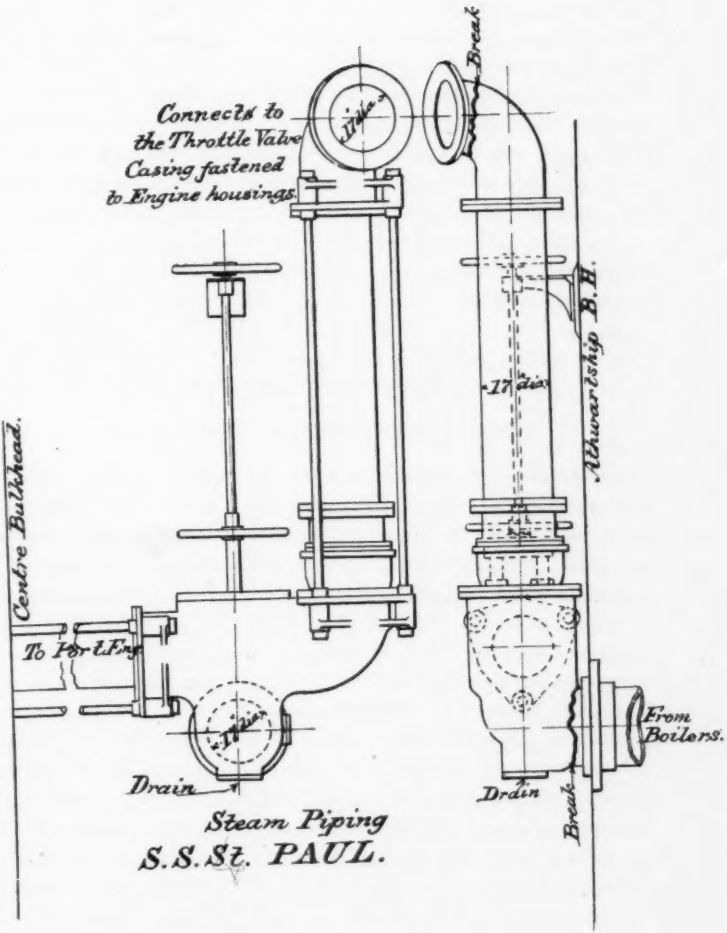
THE ACCIDENT ON THE ST. PAUL.

On December 18, 1895, while this steamer was at her dock in New York City preparatory to sailing, an explosion took place in the engine room just before 7 o'clock in the morning, killing nine persons and severely burning others. The explosion was caused by the rupture of the nozzle of the starboard engine room stop valve, which was bolted against the bulkhead and the flanges of the main steam pipe leading from the boilers. In the accompanying sketch the tie rods have been omitted from the right-hand elevation. This main steam pipe is of lap-welded iron and 17 inches in diameter. The thickness of the cast-iron stop valve at the point of rupture averaged $1\frac{5}{8}$ inches. The two high pressure cylinders of each engine received steam through this main steam pipe. The outlet nozzle of this main stop valve is on the starboard side of the valve turning upward joined to a vertical lap-welded pipe made of iron with rolled steel flanges. There is a slip joint in this length of pipe. The upper part of the pipe bolts directly to a cast-iron elbow; the other end of the cast-iron elbow is bolted directly to the throttle valve. The nozzle of the main engine room stop valve, which is bolted directly to the bulkhead, was broken circumferentially very close to the

flange, which is bolted to the bulkhead. When this broke off, the pressure of steam against the valve and nozzle pushed the vertical pipe and stop valve about two feet away from the bulkhead, which undoubtedly broke the cast-iron elbow at the upper end, which is secured to the engine throttle valve.

Fires were started in the boilers about 10 o'clock the previous evening. The boiler stop valves were opened early the following morning and before steam had formed, putting all the boilers in communication with each other and with the main steam pipe up to the engine room bulkhead. This main steam pipe, which extends to the forward set of boilers, is about 150 feet long, decreasing in diameter from 17 inches at the engine room bulkhead as it goes forward. There was about 60 pounds of steam on at 4 o'clock, and it was stated that the engine room stop valve—the nozzle of which was broken—was raised from its seat a very little, so as to allow the steam pressure to be on the other side of the valve and warm up the engine. There were four one-inch drain pipes on this length of steam pipe on the boiler side of the bulkhead—the last one being on the broken stop valve, and the valves of these drain pipes were all said to be open, and were found open after the explosion. Just before 7 o'clock in the morning, two men were sent to ease the main stop valve from its seat and open it. This valve was raised from its seat about three-sixteenths of an inch, and found in this condition after the explosion. There were no premonitory signs of water hammer, but one heavy blow was noticed by men near by. Every one in the engine room that knew anything about the circumstances was killed. The stop valves were made of cast iron, and the material of which had all been subjected to a tensile test, the minimum tensile test having been about 23,000 pounds. The pipe and valves were amply strong to sustain the working pressure of 200 pounds per square inch, and there was but 130 pounds pressure on the boiler at the time of the explosion. New valves and elbows have since been fitted, and the *St. Paul* sailed January 8th.

The jury which investigated this case concluded its verdict as follows: "We find that the said rupture was not caused



Steam Piping

S.S. St. PAUL.

by the neglect of the steamship company, or of any of its employés. We further find that the main steam pipes and the stop valves pertaining to the same were and are properly constructed to safely bear the intended working steam pressure of 200 pounds per square inch, and that the pressure on the boilers and pipes did not exceed 130 pounds at the time of said rupture. While we find that the system of drainage of the main steam pipes and stop valves is that usually provided on steamships, we recommend that the drain pipes on the main steam pipes and stop valves in question be enlarged to allow better drainage."

In connection with this explosion, reference may be made to the deductions based on the German experiments, and published on page 742 of Vol. VII of the JOURNAL.

Since the accident a pass over valve has been put on the new stop valve and the drains have been enlarged.

ASHLIN'S HIGH PRESSURE COMPOUND SYSTEM.

The steamer *Languedoc* of the Compagnie Generale des Transports Maritimes à Vapeur, of Marseilles, which was built on the Clyde in 1884, has been overhauled at the works of the Wallsend Slipway and Engineering Co., Wallsend. Her old boilers were removed and replaced by tubulous steel boilers, to work at a pressure of 160 pounds, and her cylinders were replaced by new ones of 24 inches and 63 inches diameter, by 42 inches stroke, making what is now known as high pressure compound engines, in accordance with the system of Mr. H. C. Ashlin, of Liverpool and London. The work was completed several weeks in advance of the contract time, and on Tuesday, December 3d, the vessel went on her trial trip, which consisted of a six hours' continuous run off the coast of Northumberland. During the whole of the trial trip the engines worked with the greatest smoothness, the full pressure being maintained while the ship made a speed of over 12 knots. The *Languedoc* is the third vessel which the Wallsend Co. has converted in this manner to the plans and specifications and under the supervision of Mr. Ashlin, the previous vessels being the *Mosser* and the *Colombo*. The results have been most satisfactory—sufficiently so,

indeed, to cause those who have had actual experience with the same to prefer this particular system of altering old compound machinery to the more expensive one of making them into three-crank triple-expansion engines.

The following table gives the data of an English steamer, the machinery of which was changed on the above system:

	Old machinery.	New machinery.
Cylinders, inches	34½ × 60	19 × 53
Stroke, inches	60	60
Nominal H.P.	173	191
Boilers	2 cylinders.	1 cylinder.
Furnaces	4 plain.	3 corrugated.
Grate surface, square feet	70	50
Heating surface, square feet	2,796	2,350
Steam pressure, pounds per square inch	80	160

A NEW GOUBET SUBMARINE BOAT.

A new submarine boat has been built by M. Goubet similar to that which was so much talked about a few years ago. The form of the boat is elliptic-lanceolate, with a length of 26 feet 3 inches from point to point, and a maximum diameter of 5 feet 9 inches, but it is surmounted by a small dome about 15 inches high. The material is bronze, the plates varying in thickness between ⅛ inch and ⅜ inch, and the hull is strengthed by ribs within and by three fins, of which one is in place of the keel, and the others severally on each side. The fins have the chief purpose of checking rolling, and the lateral ones form platforms for skeleton tubes, in each of which an auto-mobile torpedo rests. The torpedo is driven by compressed air, and leaves the tube through the checking mechanism of its screw being released. The immersion of the submarine boat depends upon the quantity of water admitted to a reservoir or expelled from it. The pumps for this purpose are worked automatically by a dynamo, the motion of which is determined by a manometer, thus enabling the desired depth to be maintained. A like arrangement is employed to secure the longitudinal trim of the boat. The craft is propelled by means of a screw driven by a dynamo, and there are oars on

each side worked from within through watertight bearings. The vitiated air is expelled from the boat and replaced from reservoirs of compressed oxygen. The displacement is about ten tons, and with all on board the craft is calculated to preserve a small margin of buoyancy; but, in case of mishap, a weight of about 24cwt. can be detached from the keel, and the boat will then rise to the surface. At slight depths a kind of telescopic tube, having a length of some 10 feet, furnished with two reflecting prisms, will enable an observer in the boat to see what is going on above. In addition to being fitted for employment as a submarine torpedo boat, the new craft, according to her builder, can be furnished with shears for cutting torpedo nets, cables, and the connecting wires of mines. She is about to be put under trial at Argenteuil, on the Seine.

SHIPS.

Kearsarge and Kentucky, Battleships Nos. 5 and 6.—The bids for these battleships (a description of which was given on page 801 of Vol. VII) were opened at the Navy Department on November 30, 1895. Three firms submitted the following bids:

	One ship.	*Two ships.*
Newport News Shipbuilding and Dry Dock Co., Newport News, Va., on the plans of the Navy Department	$2,350,000	$4,500,000
Union Iron Works, San Francisco, Cal., on the plans of the Navy Department	2,740,000	5,280,000
On their own plans	2,650,000	5,280,000
Wm. Cramp & Sons' Ship and Engine Building Co., Philadelphia, Pa., on the plans of the Navy Department	2,820,000	5,500,000
On their own plans	2,500,000	4,900,000

Besides these bids, the Messrs. Cramp & Sons submitted another one, with the following novel features:

Two battleships complete, on their own plans, for hull, machinery, armor and armament, and one battleship, but without the armament, for the amount allowed by law, namely, $8,000,000; or, two battleships complete, including armament, for $7,700,000. The contract for these two battleships was given to the Newport News Company.

Helena.—Gunboat No. 9, sister ship to the *Wilmington* and described on pages 727–729 of Vol. V, and page 176, Vol. VI, was launched by the Newport News Ship Building and Dry Dock Company on the 30th of January, 1896.

Revenue Cutter No. 3.—Bids for the construction of this cutter, intended for service on the Pacific Coast, were opened at the Treasury Department on the 8th of February, the bidders and the building prices being as follows:

	Name of bidders.	Amount of bid.	Time of completion.
1.*	John M. Brooks, East Boston, Mass..	$185,000.00	One year from date of contract.
2.	Atlantic Works, East Boston, Mass..	235,000.00	Twelve months. Delivered at New York.
3.	John H. Dialogue, Camden, N. J..	Mod'd spec. 198,000 00	Sixteen months from date of contract. At Camden.
4.	The Harlan & Hollingsworth Co., Wilmington, Del...	220,000 00 200,000.00	December 1, 1896. Delivered at New York.
5.	William Cramp & Sons, Philadelphia, Pa...	198,000.00	January 15, 1897. Delivered at Philadelphia.
6.	Union Iron Works, San Francisco, Cal..	Sp'l spec. 245 000.00 199,750.00	February 8, 1897. Ten months from date of contract. Delivered at San Francisco.

* No. 1 was an informal bid.

The bid of the Messrs. Cramp & Sons, of Philadelphia, was the one accepted.

The new cutter is to be of composite build, 219 feet long over all, 200 feet long between perpendiculars, to have 33 feet 4 inches breadth of beam and a depth of hold of 17 feet 10¼ inches. Her displacement at a mean draught of 14 feet will be about 1,280 tons. There will be four Scotch boilers and one triple-expansion engine capable of developing 2,000 horse power.

ARGENTINE REPUBLIC.

Torpedo Boat Destroyers.—A contract has been given to Messrs. Yarrow & Co., Poplar, Isle of Dogs, for four destroyers of about the same dimensions as those of the *Sokol*. They are to have a speed of 29 knots and their displacement is to be 240 tons.

AUSTRIA.

New Ram Cruiser "D."—This armored ram cruiser of an improved *Maria Theresia* type, allowed in the appropriation for 1896, has been laid down in the private works at San Rocco, near Trieste.

The length will be 367.5 feet, beam 55¾ feet, and the displacement, 6,004 tons.

There will be an armor belt of harveyized or nickel steel, 10.6

inches thick at the heaviest part, surmounted by an armored citadel, 9.8 inches thick. The protective deck will be 1.5 inches thick. The usual double bottom and numerous water tight compartments will be fitted. The bunker capacity will be very large.

The armament will consist of two 9.45-inch Krupp guns in turrets worked by electricity, eight 5.9-inch Krupp rapid fire guns, four of these in armored redoubts, and several rapid fire guns of smaller calibers on the superstructure and in the tops of the two military masts.

There will be twin screw engines, which under forced draft are expected to develop about 12,000 I.H.P. and give the vessel a speed of 20 knots. Water tube boilers will be installed.

The total cost of this cruiser is estimated at $3\frac{3}{4}$ million florins, or about $1,500,000.

CHINA.

Fei Ying.—In addition to the information given on page 811 of Vol. VII, the following particulars are now available:

The total grate surface of the eight Yarrow boilers is 230.4 square feet, and the total heating surface, 13,993 square feet. The working pressure is 220 pounds per square inch.

The twin screw engines are of the triple expansion, four-cylinder type, and are balanced according to Mr. O. Schlick's patent. On the measured mile runs, the I.H.P. was from 5,400 to 5,600. The boilers worked without trouble, although only four of the eight firemen were trained men, and these only in firing with ordinary Scotch boilers of the merchant service.

The trial was conducted under the supervision of German naval officials and under the regulations governing trials in the German Navy.

Two Torpedo Boats.—These were built by the Vulcan Company, of Stettin, and on their trials developed from 1,600 to 1,750 I.H.P., with an air pressure of $1\frac{3}{4}$ inches.

Each boat has two Yarrow boilers with a total grate surface of 58.13 square feet, and a total heating surface of 3,498 square feet. The working pressure is 220 pounds per square inch.

There is one engine of the same type as mentioned above for the *Fei Ying*.

On the passage to Nanking, China, which both boats made under their own steam, while one of the boats was steaming at 10 knots under one boiler, a tube burst. No especial inconvenience was caused, the boat being under way with the second boiler in about two hours.

Both boats, on reaching Nanking, were in good condition.

ENGLAND.

Empress of India.—This battleship will be fitted with the new system of piping which is intended to prevent freezing in the hydraulic pipes. The change consists simply of introducing a copper steam pipe inside of the hydraulic pipe, which is generally of manganese bronze. This system has already been adopted in the Russian Navy, and will be applied to all British vessels as fast as they go to a dock yard for repairs.

Jupiter.—This first-class battleship of the *Magnificent* class (described in detail on pages 161–167 of Vol. VII) was successfully launched from the works of the builders, Messrs. J. & G. Thomson, Clydebank, on Monday, November 18, 1895. The following particulars are in addition to those previously given:

The coefficient of fineness of the hull below the water line is 0.65; the eight boilers are single ended; the launching weight was estimated at about 7,000 tons; the complement of officers and men will be about 770.

The estimated cost of the vessel and armament is $4,912,650.

Renown.—This battleship, described on page 427 of Vol. VII, recently steamed from Pembroke to Devonport, where she is to be completed.

The builders of the machinery, Messrs. Maudslay, will receive a premium of $7,500 in addition to the contract price of $417,800, for completing the machinery before the contract time (November 15, 1895).

The following particulars of this vessel are in addition to those already given.

The weight of the hull is 8,020 tons. The hull plating aver-

ages 25 pounds to the square foot amidships and tapers to 18 pounds at the ends. Bilge keels extend along two-thirds the length of the vessel. There are 75 water tight compartments.

The side armor belt extends 5½ feet below and 10 feet above the water line for a length of 220 feet. The remaining 80 feet of the vessel at each end are protected by the 3-inch deck only. The side armor is backed by 9 inches of teak.

At each end of the belt there is an athwartship armored bulkhead of harveyized steel, the thickness ranging from 10 to 6 inches.

The following detailed description of the machinery is taken from "Engineering," London:

The machinery weighs, with water in boilers, 1,300 tons. The engines are of the triple expansion type, and the boilers of the single-ended cylindrical tubular type. They are of a general arrangement now adopted in our Navy, but the details are interesting, as suggesting the practice of the constructors, Messrs. Maudslay, Sons and Field, Limited, Lambeth. The engines running at 100 revolutions, equal to a piston speed of 850 feet per minute, with steam at 155 pounds pressure, develop 12,000 indicated horse power, with an air pressure in the closed stokehold not exceeding 1 inch. At natural draft, the pressure not exceeding ½ inch, the power is to be 10,000 indicated horse power.

The diameters of the three cylinders are respectively 40, 59 and 88 inches, the stroke being 51 inches. They are of cast iron, each being a separate casting, and the thickness of walls is for high pressure and intermediate cylinders 1⅛-inch, for low pressure 1⅜-inch. They are braced together by a tie rod of steel bolted to the cylinders. The cylinders are inverted, and are carried on cast-steel standards both at back and front, with cast-iron crosshead guides bolted to their face. The bedplate is of cast steel.

The valve of the high pressure cylinder in each engine is of the piston type, those on the intermediate and low pressure cylinders of the double ported flat type. The valves are worked by the usual double eccentric link gear, the go-ahead rod being as usual the straight rod. The valves are reversed by an inde-

pendent steam engine working a worm and wormwheel of the all-round type.

There are four lengths of straight shafting—the thrust, two intermediate, and one propeller—the total length being 125 feet. The thrust block, although placed in the after end of the engine room, is not connected with the engine bed plate. The thrust surface is 1,425 square inches for each engine, there being seven collars of the usual horseshoe type, lined with white metal, while the blocks are of cast iron. The intermediate shafts are 14¾ inches in external diameter, supported at intervals on plummer blocks with white metal bearings. The stern or propeller shaft is 15¾ inches in external diameter, and, as in the case of all the shafts, has an 8-inch hole. The stern shaft is 32 feet 8 inches long, and there are lignum vitæ bearings at either end, the forward one being 2 feet 7½ inches long and the after 3 feet 6 inches.

The screw propellers have each four blades of manganese bronze with gun metal boss. The diameter is 16 feet and the pitch 21 feet. Both propellers turn outwards.

The condenser for each engine is placed in the wing of the ship, alongside of the L.P. engine. It is of gun metal, with horizontal tubes of brass, through which the circulating water passes. The cooling surface in each condenser is 13,500 square feet. The air pump is worked from the intermediate cylinder crosshead. The pump, which is single acting, is of gun metal, the cylinder being 33 inches in diameter by 22 inches stroke. The circulating pump has a vertical steam engine 12 inches in diameter by 15 inches stroke, the impeller being 4 feet. This pump was made by Messrs. Maudslay. In connection with this and other auxiliary engines there is a separate condenser having a cooling surface of 1,800 square feet and its own air and circulating pumps.

There are eight single-ended four-furnace boilers arranged in four separate compartments. Each boiler is 16 feet 6 inches in diameter by 10 feet 3 inches long, with two separate combustion chambers, into each of which two furnaces open. The 32 furnaces have Fox's corrugated flues, the mean diameter being 3 feet 8 inches and the length of grate 7 feet. The total grate

area is 821 square feet. The tubes are of steel, the ordinary tubes being .16 inch and the stay tubes .25 inch thick. The ordinary tubes are swelled at the front end to $2\frac{9}{16}$ inches outside diameter and expanded. The stay tubes are swelled to $2\frac{13}{16}$ and $2\frac{11}{16}$ inches outside diameter at the front and backs respectively, and are screwed into both tube sheets. The tubes number 4,640, 3,536 ordinary and 1,104 stay tubes, and are 7 feet $0\frac{3}{4}$ inch between tube plates, the diameter being $2\frac{1}{2}$ inches. The total tube surface is 21,448 square feet, and the total heating surface 24,840 square feet. Both boiler heads are flanged in and flat. The shell consists of two courses. The circumferential seams are double riveted and the longitudinal seams treble riveted with double butt straps. There are three rows of $2\frac{1}{4}$-inch through screw braces in the steam room, spaced $16\frac{1}{4}$ inches vertically and 16 inches horizontally.

There are eight forced draft blowers, two for each compartment. They are double breasted, 6 feet in diameter, and are each run at 320 revolutions per minute by an engine 8 inches by 6 inches stroke. Incidentally it may be remarked here that Messrs. Maudslay have also fitted 18 ventilating fans to the ship. The boilers exhaust into two uptakes and funnels. The latter are oval, 9 feet by 6 feet 8 inches, the height above the dead plates being 90 feet. No feed heaters have been fitted, but filters manufactured by Messrs. Maudslay have been fitted to the main feed engines.

Messrs. Maudslay have also supplied several auxiliary engines to the ship. The electric lighting plant consists of a pair of compound engines with cylinders 9 inches and $13\frac{1}{2}$ inches in diameter by 8 inches stroke, each coupled to a Siemens $\frac{16}{19}$ dynamo to give 400 amperes and 80 volts at 300 revolutions per minute.

The air compressing plant consists of four complete engines, having three cylinders $8\frac{1}{4}$ inches in diameter and 4 inches stroke, working at 350 revolutions per minute. The plant is so arranged that each cylinder can work each or any compressor. The pumps compress air up to 1,700 pounds per square inch with four compressions. There are eight 50-tube reservoirs, the length of tubes being 6 feet, and the diameter $2\frac{5}{8}$ inches. Each reservoir has capacity for 11 cubic feet of air.

The engines for steering the ship are by Messrs. Caldwell & Co., Glasgow, and are of the horizontal type, with cylinders 12 inches in diameter by 10 inches stroke. This engine operates a phosphor-bronze worm which gears into a cast-steel worm wheel fitted on the steering shaft.

The distilling machinery, by Messrs. Caird and Rayner, consists of two evaporators capable of producing altogether 560 gallons of fresh water per hour, and two distillers, fitted to produce 200 gallons of fresh drinking water per hour. There are two sets of pumps for circulating sea water through the distilling condenser, and two sets for circulating cooling water in the distillers, feed evaporator, or pumping the distilled water into fresh water tanks.

The boat hoisting machinery made by Messrs. Clarke, Chapman & Co., includes two independent engines, each having two cylinders 14 inches by 9 inches stroke. The engines are reversed and controlled by a gun-metal controlling valve placed between the cylinders and fixed on the bed plate, and worked by a hand-wheel. The maximum load test with a single wire rope and with steam at 140 pounds is 17 tons, while 8½ tons is to be raised 30 feet per minute with 90 pounds steam pressure.

The armament consists of four 10-inch 29-ton guns mounted in barbettes forward and aft, a pair in each. The mounting has been supplied by Sir J. Whitworth & Co., and, as in the case of the guns of the *Centurion* and *Barfleur*, is of the all-round loading arrangement. The rotating weight is 210 tons, and each gun can be trained through 240 degrees in five minutes. The training and elevation is done by hand gear. The angle of fire is unusually high, 35 degrees. This arrangement of mounting differs from that on the *Barfleur* only in unimportant details. The auxiliary armament consists of ten 6-inch quick-firing guns, fully protected by casemates, and 22 smaller quick firers.

The armor of the ship consists of side plating of harveyized steel 8 inches to 6 inches thick, with an armored bulkhead fore and aft of 6 inches to 10 inches harveyized steel, while the barbettes have 10-inch steel similarly treated. The big guns, too, are shielded by nickel steel 6 inches thick, so sloped as to greatly increase the resistance to shot approaching horizontally. The

protective deck is 3 inches and 2 inches thick, is flat, and covers in all the machinery, magazines, &c. It will, therefore, be seen that the battleship is of a most serviceable type, and as Lord Brassey, in commending the type, remarked, it is some consideration to be able to get four *Renowns* for the price of three *Magnificents*. We could at the present juncture quite afford to lay down ten *Renowns*.

Blake.—This armored cruiser, previously described on page 121 of Vol. IV, of the JOURNAL, has recently undergone extensive repairs to her boilers. It will be remembered that the double-ended boilers had one common combustion chamber for the eight furnaces. During the refit at Chatham dock yard, separate combustion chambers for each end have been put in, the boilers retubed, and the new steel tubes fitted with the Admiralty ferrules. Repairs were also made to the hull and to other parts of the machinery, the cost of the repairs amounting to about $80,000.

The trials of the machinery after repairs were held in November, and consisted of an eight hours' run under natural draft, from the Tongue off Sheerness to Dungeness and back, and a four hours' run under forced draft.

On the preliminary trial, the I.H.P. developed was 20,132 and the speed 21.5 knots by log.

The results of the four hours' forced draft trial, November 6, 1895, are as follows:

Draught, forward, feet and inches					24–10
aft, feet					27
Speed, by patent log, knots					20
Steam pressure in boilers, pounds per square inch					147
Air pressure in fire rooms, inches of water					2.3
Revolutions per minute,		starboard	96.5	port	99.1
		Forw.	*Aft.*	*Forw.*	*Aft.*
Vacuum in condensers		26.8	26.3	26.9	26.5
Mean pressure in cylinders	High	54.7	50.8	55.8	52.5
	Intermediate	39.0	40.2	37.2	35.9
	Low	14.4	13.2	14.5	14.5
Indicated horse power, mean for each set		4.938	4.773	5,008	4.860
Total (starboard and port)			9,711		9,868
Grand total				19.579	

Juno.—This second-class cruiser, similar to the *Venus*, described on page 815 of Vol. VII, was launched at Barrow, on Saturday, November 16, 1895, by the Naval Armaments and Construction Co. The same company is building the sister ship *Doris*.

The vessel is of steel, sheathed and coppered, and has a length of 350 feet; beam, extreme, 54 feet; mean load draught, 20.5 feet and displacement of 5,600 tons. The *Juno* and *Doris* have six inches more beam than the *Talbot* class of cruisers, but are in other respects the same.

The armament consists of five 6-inch, six 4.7-inch, nine 12-pounder and seven 3-pounder rapid fire guns, four Maxim machine guns, and three torpedo tubes, two of which are submerged.

The stem, stern post and rudder are of phosphor bronze.

The following additional particulars of the machinery are taken from "The Marine Engineer," London:

There are two inverted, direct acting, triple-expansion engines, in separate compartments. The cylinders are 33, 49 and 74 inches in diameter and have a stroke of 39 inches. Piston valves are fitted on the H.P. cylinder, and double ported slide valves on the I.P. and L.P. cylinders. The ordinary link motion is used. The crank shaft of each engine consists of three interchangeable parts. The back columns are of the inverted V form with the crosshead guides attached; the front supports are the usual wrought-steel columns braced horizontally and diagonally. The air pumps are worked from the H.P. crosshead and deliver through filters into the feed tanks. The main condensers are of naval brass, cylindrical, and have a total cooling surface of 10,600 square feet. Auxiliary condensers are fitted. Other auxiliary machinery in the engine rooms consist of two main feed pumps, four fire and bilge pumps, two other pumps which can also be driven by the main engines, a drain tank pump, two dynamos and their engines, two turning engines, two sets of air compressors and reservoirs, two ventilating fans, the evaporators and the distilling plant.

There are eight single-ended steel boilers in two separate

compartments. Each boiler has three corrugated furnaces with separate combustion chambers. Eight blowers are fitted for the closed fire room forced draft system.

The steam steering gear is aft below the water line.

Vindictive.—In addition to the general dimensions already given on page 419 of Vol. VII of this unsheathed second-class cruiser, which has been laid down at the Chatham dockyard, the following particulars of the armament and the boiler installation are available:

The armament will consist of four 6-inch guns which will have fore-and-aft fire, six 4.7-inch guns and eight 12-pounders mounted on the broadsides.

The water tube boilers will be of the Belleville type, 18 in number, and to be built by Messrs. Maudslay, Sons, and Field, who are making the feed pumps, also of the Belleville type, and the air blowers or compressors for supplying air to each furnace to mix with the gases and aid combustion. The boilers are arranged in three groups, each group consisting of six boilers placed back to back, with athwartship stokeholds. Each boiler is constructed for a working pressure of 300 pounds per square inch, and consists of eight elements, 10 stories high, built of solid drawn steel tubes, $4\frac{1}{2}$ inches in diameter and 7 feet 6 inches long. The boxes connecting the tubes are of malleable cast-iron. The total grate surface is 880 square feet, and the total heating surface 25,600 square feet. There are six feed pumps, each capable of feeding six boilers, and six air blowers, that is, one feed pump and one blower in each stokehold.

The armament and boiler installation will be the same on the other cruisers of this class—the *Gladiator*, to be built at the Portsmouth dockyard, the *Arrogant*, building at the Devenport dockyard, and the *Furious*.

Diana.—This second class sheathed cruiser of the *Talbot* type (a general description of which was given on page 427 of Vol. VII, and some further particulars, under the sister ship *Venus*, on page 815 of Vol. VII), was successfully launched on December 5, 1895, by the Fairfield Shipbuilding and Engineering Co.,

Govan, Glasgow. From the time of laying the keel blocks to the day of launching 235 working days have passed.

The ram stem, stern post and propellers are of bronze.

The estimated cost of hull and machinery is about $1,500,000. The complement of officers and men will be 450.

Phœnix.—This twin screw sheathed sloop, described on page 428 of Vol. VII, completed satisfactory natural and forced draft trials in the channel on January 14 and 18, with the following results:

	Natural draft.	Forced draft.
Duration of trial, hours	8	4
Steam pressure, pounds per square inch	147	159
Vacuum, inches of mercury, starboard	27.	26.1
port	24.8	24 9
Revolutions per minute, starboard	182.9	252.
port	189 2	239.
I.H.P	1,181	1,491
Air pressure, inches of water	0.61	1.14
Speed by log, knots	13 4	13.4

The speed obtained on the natural draft trial is over one knot greater than that originally expected. After this trial it was expected that on the forced draft trial at least another knot would be obtained, but, as the figures show, the speed was exactly the same for both trials. The machinery was built at Keyham.

The weight of the hull is 510 tons. The bunker capacity at load draught is 130 tons. There is a considerable spread of canvas.

Astræa.—Since the original plans of the cruisers of the *Astræa* type were prepared, the vessels have been subjected to several structural alterations, besides changes in their equipment, and the result is that their actual mean load draught is considerably more than their designed draught. Notwithstanding this, the vessels have been copper sheathed in accordance with the original plans, and on more than one occasion, when they have been well laden, their copper sheathing has been entirely immersed. It has now been decided that the sheathing of all vessels of this class is to be increased in height by one foot, and the *Astræa*

will have this done before she leaves Devonport for the Mediterranean.—" Engineers' Gazette," London.

The vessels belonging to this class are the *Astræa*, *Bonaventure*, *Cambrian*, *Charybdis*, *Flora*, *Forte* and *Hermione*, their designed displacement being 4,360 tons and designed draft 19 feet.—(Edit.)

Alert and Torch.—These sloops have had their coal consumption and endurance trials. The first five days' trials of the *Alert* were stopped at the end of 84.5 hours on account of rough weather, and those of the *Torch* at the end of 94.5 hours on account of an accident to the machinery. The following are the particulars of the trials:

	Alert.	*Torch.*
Place of trial	English Channel.	North Sea.
Duration of trial, hours	84.5	94.5
I.H.P.	657.9	660.8
Coal per I.H.P. per hour, pounds	1.75	1.94

The weather during the whole of the trial of the *Torch* was bad.

The *Torch* made two more attempts to run a five days' continuous trial. The last one had progressed for 114 hours, when fog stopped further trials. This trial has been considered satisfactory, and the vessel will be passed into the Reserve fleet. The coal consumption on the last trial was 1.88 pounds per I.H.P. per hour.

Seagull.—This torpedo gunboat is to be fitted with six tubulous boilers of the Niclausse type, to be supplied by Messrs. Humphreys, Tennant & Co., Deptford, in place of the old locomotive boilers now in this vessel.

Lightning.—This torpedo boat destroyer, of which a general description was given on page 425, Vol. VII, had her official speed and coal consumption trials in November, the latter being brought to a sudden stop at the end of about eleven hours by collision of the *Lightning* with the steam barge *Belvedere* at the mouth of the Thames. The destroyer was seriously damaged, but was safely navigated to port. An account of the collision is given below.

On the three hours' full speed trial on November 5, the average speed attained was 27.944 knots, the mean speed of the six runs over the measured mile being 28.274. The fastest mile was run in 1 minute 55 seconds, or at the rate of 31.3 knots. The average steam pressure was 195 pounds per square inch, the average number of revolutions per minute 368, and the total coal consumed, 14 tons. The I.H.P. was about 4,100.

During the trial there was an entire absence of flames from the smoke pipe and no vibration was noticeable.

Turning, stopping and starting trials were next made, the vessel going from full speed ahead to full speed astern in seven seconds.

The following account of the collision and the damages sustained is taken from "Engineering," London.

On Friday, November 9, the *Lightning* collided with the London County Council's steam hopper barge *Belvedere* at the mouth of the Thames; the accident reflects satisfactorily on the design and workmanship, since the vessel was able to steam home without very much apprehension on the part of the navigators as to her condition. Having previously passed the speed tests with splendid results, the *Lightning* was undergoing her 12 hours' consumption trial. All went well until seven o'clock at night. The vessel was then between the Mouse and Nore Lightships, and steaming in the direction of Sheerness at a rate of 12 knots per hour, and it was expected that she would reach that port about eight o'clock, which would have completed the 12 hours' run. A thick mist hung over the sea at the time, and the *Lightning* suddenly came into collision with the *Belvedere*, which she struck between stern and amidships. The impact was so severe that the *Lightning* seemed to be almost lifted out of the water, and was swung violently round, making almost half a circle. For the moment many on board had expected that the *Lightning* might sink, but it was soon realized, however, that the vessel, although badly injured, was capable of steaming to port. But the troubles of the *Lightning* were not over yet. In the mist the *Lightning* grounded on the Maplin Sands, where she remained from nine o'clock on Friday night until four on Satur-

day morning, when she floated off, and steamed to the Chatham Dock Yard.

A fishing smack kept the vessel company, in case it should be necessary to take the crew off, for the single boat carried by the *Lightning* would accommodate scarcely twenty persons, whereas there were some eighty on board the vessel. The *Lightning*, in her damaged state, came successfully through a very severe trial, although the smooth sea reduced the degree of danger.

On returning to Chatham she was at once docked, and the full extent of the damage ascertained. The bow, as originally constructed, is designed on very fine lines. The stem is a light forging; the frames are of steel and stiffened by reverse frames. The shell plating is also of steel, with double riveted laps at keel and sheer strake and single elsewhere; the butts are treble riveted at keel and sheer strake and double elsewhere. The bow is stiffened besides by a side stringer worked inside on the frames, which runs longitudinally midway between the upper and lower decks, and at the level of the lower deck by a breast hook and stringer plates.

The damage to the bow is very considerable, the plating and frames being crushed into all manner of shapes for about twelve feet from the stem. The upper part of the bow sustained the most damage, probably owing to the overhang of the *Belvedere's* quarter where she struck. The collision bulkhead, which is situated about six feet from the stem, was completely smashed and torn in halves. The next, or chain locker bulkhead, five feet three inches further aft, held on, however, and, notwithstanding the great strain brought to bear upon it, was found to be quite water tight and no water entered the ship abaft. Thus the water was fortunately confined to the two narrow compartments forward of this bulkhead and consequently the buoyancy of the ship was not materially altered from her normal condition.

The danger of the situation, however, was great. A portion of the shell plating above the water line was ripped off abaft the chain locker bulkhead, and the door on the upper part of the bulkhead was open, so that if the sea had increased, the large compartment, the forward crew space, would probably have be-

come flooded. However, after some difficulty the door was closed, and the hole in the side was temporarily barricaded. A large portion of the bow, containing the hawse pipes, part of the turtle deck plating and a considerable portion of the shell plating, was torn clean away from the ship, and lay suspended over the port bow by the cables, being a source of great anxiety lest, if the ship should roll, it would knock a hole through the thin plating forming the shell of the ship.

One of the features noticed on the survey of the bow in dock, was the excellence of the material used in its construction. In some places the plating and frames were doubled up like a concertina, and in no case was there a sign of fracture in the material; in fact, the ductility of the steel was perfect. This is the more gratifying to the builders of the vessel, as the whole of the material used in her construction was rolled in their own works at Jarrow.

After the collision occurred the fog increased considerably, and the utmost exertions were made to clear the anchors with a view to anchoring the vessel until the fog lifted, but they were hopelessly fouled in the wreckage over the bow, and before they could be cleared the vessel had drifted on to the ground. Owing to the peculiar position of the propellers in this class of vessel, it was known that she was simply settling on the tips of her aluminum-bronze propeller blades, and it says much for the strength of the ship that, though she was seven hours in this position, beyond the propeller blades being bent considerably, the shaft struts and the hull in their vicinity were not in the least damaged.

Rocket, Surly and Shark.—The following details of the machinery and trials are taken from "Engineering," London, and are in addition to or correction of the particulars already given on page 423 of Vol. VII. It will be remembered that all copper tubes in the boilers were replaced by steel, after several accidents to copper tubes had happened.

The two engines are placed in one compartment aft of the boiler rooms, and the four boilers in two compartments. The furnaces of the forward and after boilers discharge into separate

funnels, while those of the two center boilers lead up to a common central funnel of larger size than the other two.

The cylinders are 18⅛, 26⅝ and 40⅛ inches in diameter, the stroke being 18 inches. The high pressure cylinders are placed forward, and they, together with the intermediate cylinders, are fitted with piston valves of the inside type, placed on their forward sides, the low pressure cylinders having outside piston valves placed aft of the cylinders.

The valve gear is of the double eccentric link motion type, and is adjustable. Metallic packing has been employed for all stuffing boxes of the piston and valve spindle rod glands.

The cylinders, which are entirely independent castings, are bolted together to provide sufficient longitudinal stiffness, and stayed transversely between each other, as well as to gusset plates in the wings connecting the deck beams and frames. A forward longitudinal strut extends from each of the high pressure cylinders to a gusset plate between the deck and the forward bulkhead of the engine room, and two similar ties secure each of the low pressure cylinders to the after structure of the vessel. The cylinder bottoms are separate castings, and are bolted to the cylinders, and they, together with the cylinder covers and the top and bottom covers of the valve casings, are of cast steel. The pistons are of forged steel turned all over, and are each fitted with four Ramsbottom rings. The piston and connecting rods are of wrought steel, and are hollow. The crosshead pin is fixed into the forks of the connecting rod, and is of steel, case hardened. The piston rod guide and head are forged with the rod, and the guide has machined recesses on the ahead side, which are filled with white metal. The ahead guide faces are of cast iron, with water circulation at the back, and the astern faces are of bronze.

The bed plates are of cast steel. Each consists of two angle bar-shaped castings, which extend the whole length of the engine, and rest on longitudinal frames extending between the engine room bulkheads. The main bearing frames extend between, and are checked into these castings, being secured to them, as well to the floors of the vessel, by fitted bolts. The main bearings

are five in number, a single bearing of extra length being placed between the intermediate and low pressure cylinders, wrought-steel columns, braced together near the middle, form the connection between the cylinders and each of these frames.

The crankshafts and pins are hollow, of steel, and are each forged in one piece. The thrust shafts and propeller shafts are likewise of steel, and hollow. The propellers have each three blades of manganese bronze dovetailed into a boss of forged steel, the bosses being fitted with guards and caps, in conformity with Admiralty practice.

The condensers are placed in the wings, the cooling surface being 3,000 square feet. The tube casings are sheet copper and the tubes are $\frac{5}{8}$ inch in external diameter by .05 inch thick. Water is circulated through them by two of Gwynne's centrifugal pumps, assisted by a natural flow due to the velocity of the vessel. The air pumps are single acting, and are driven by separate double armed cranks engaging the forward ends of the crankshafts by transverse feathers, and each discharges into separate feed tanks.

There are four Normand water tube boilers of the earlier type. The tubes in the rows nearest the fire are of steel, and the tubes forming the outside wall, of galvanized steel. The grate area is 163 and the heating surface 8,600 square feet. A single breasted fan, 5 feet 6 inches in diameter, is placed at the side of each boiler room for forcing the draft, the engines being of the open vertical type. Air is admitted to the fans by large cowls placed directly overhead.

The arrangements made for feeding the boilers are very complete, and consist of a main and auxiliary system of pumps and pipes, which are separate and entirely independent of each other. The main system consists of two of Messrs. G. and J. Weir's special feed pumps, placed at the forward end of the engine room. Each draws from one of the two feed tanks by an independent pipe, and discharges to either of the boilers in one compartment direct, or through one of two Normand feed heaters placed against the forward bulkhead of the engine room between the pumps. For the auxiliary system a similar feed pump is

placed in each of the boiler rooms, and each pump is connected by separate pipes with the reserve fresh water tank, one of the feed tanks, and with the sea, and discharges direct to the boilers; the pump in the after boiler room also discharges to the deck, and serves the purpose of a fire pump.

The main steam pipes are of copper, served with copper wire. An independent pipe extends between each boiler room and one set of engines, and each pipe is fitted with a self-closing stop valve at the engine room bulkhead, where they are cross connected, besides an equilibrium valve at the high pressure cylinder. An independent auxiliary steam pipe supplies all the auxiliary engines, except the main feed pumps. The exhaust steam is led by a system of pipes to each of the main condensers.

The distilling apparatus is situated at the after end of the engine room, and consists of a large evaporator, capable of making 2,250 gallons of fresh water per day. A distilling condenser is provided which can supply 450 gallons per day of pure aërated fresh water, chiefly to be used for ship's purposes, and the remainder of the vapor is condensed in the main condensers to serve as make-up feed. A separate engine with pumps is fitted for maintaining the water level in the evaporators, circulating the condensing sea water, and pumping the drinking water into the ship's tanks, and also for pumping the gained water from the main condensers to the reserve fresh water tanks. An auxiliary air pump is also fitted to each of the circulating pumps, and is connected to the bottom of the main condensers and discharges to the feed tanks.

The remaining pieces of auxiliary machinery placed in the engine room may now be briefly noticed. Two powerful sets of air compressing engines and pumps are placed at the after bulkhead, and immediately beneath the deck is fixed the steering engine. On the same bulkhead is fixed a duplex bilge pump of Admiralty pattern. Each of the main steam pipes is drained by a Normand steam trap placed in the engine room, and all the condensed water accumulating in the auxiliary steam and exhaust pipes is drained by a system of pipes into the feed tank.

Mechanical reply telegraphs are fitted for each set of engines, with transmitters inside and outside the conning tower, and at the after steering station. Mechanical telegraphs are fitted between the engine room and stokeholds, and an extensive system of voice pipes between the engine room and all the principal stations and apartments of the vessel is provided. Mechanical revolution indicators of special design are fitted to each of the engine shafts and placed in such positions that they may be read from the deck as well as from the starting platform.

Annexed is a tabulated statement of the results obtained on the official trials. These trials consisted of three hours' continuous steaming, during which the guaranteed speed of 27 knots had to be maintained, and six runs on the measured mile at Skermorlie, the final speed being calculated as usual from the total revolutions for the three hours, based on the mean revolutions per knot obtained from the measured mile runs.

	H.M.S. *Rocket*. Feb. 27, 1895.		H.M.S. *Shark*. March 1, 1895.		H.M.S. *Surly*. March 15. 1895.	
	Mean of		Mean of		Mean of	
	Six miles.	Three hours.	Six miles.	Three hours.	Six miles.	Three hours.
Revolutions per minute — port	399	.....	400	.....	396.1	.....
Revolutions per minute — starboard	397	.....	397	.....	399 7	.....
Revolutions per minute — mean	398	396	400	401	397 9	403 8
Steam pressure, pounds per square inch	188	.....	184	.....	187	.....
Vacuum, inches	25	.....	25	.....	24 7	.....
Air pressure, inches of water	3 5	.....	3	.....	3·35	.....
Indicated horse power	.....	4.200	.....	4,250	.....	4 175
Speed, knots	27.7	27 4	27.5	27.6	27.59	28.05

Rocket.—On January 16, the *Rocket* left Plymouth to join the "Flying Squadron." Soon after, the new tubes of boiler No. 3 began to leak, and later leaked so much that the vessel was forced to return. On examination next day the tubes were found in bad condition, requiring nearly a week's time, day and night, to remedy the defects. A large number of tubes had to be renewed.

Hart.—This torpedo boat destroyer was built by the Fairfield Shipbuilding and Engineering Company, Govan, and launched on March 27, 1895. On December 20, 1895, the three hours' full power trial was to be made, but fog prevented it. On the following day the trial was undertaken, but, after running for two hours, one of the blower engines broke down and the trial was stopped.

On December 31, the three hours' trial was successfully completed with the following results: Draught, forward, 5 feet $\frac{1}{2}$ inch, aft, 7 feet $6\frac{3}{4}$ inches, mean, 6 feet $3\frac{5}{8}$ inches; steam pressure in boilers, 196.1 pounds per square inch; air pressure, $2\frac{3}{4}$ inches; I.H.P., 4,143; speed, 27.075 knots; coal per I.H.P. per hour, 3.2 pounds.

She is to be fitted with Holden's system of burning liquid fuel, and trials are to be made.

Hunter.—A sister ship to the *Hart*, was launched on December 28, 1895, by the Fairfield Shipbuilding and Engineering Company, Govan. The other 27-knot destroyer built by this company is the *Handy*, a few particulars of which were given on page 426 of Vol. VII. The engines are triple-expansion and are designed to develop about 4,600 I.H.P.

All three of these destroyers have new Thornycroft boilers.

Haughty.—This torpedo boat destroyer, a few particulars of which were given on page 823 of Vol. VII, completed her official trials about the middle of December, with the following results.

Six runs over the measured mile were made at the following speeds:

	Knots.
First mile,	26.66
Second mile,	26.08
Third mile,	27.17
Fourth mile,	27.375
Fifth mile,	28.125
Sixth mile,	28.125

The average of these speeds is 27.241, the mean number of revolutions per minute being 371. After these runs, a three-hours' run with full power was made, the average speed attained

being 27.4 knots, the maximum for a short period being 28.7 knots. The displacement on trial was 231 tons, and the I.H.P. developed a little over 4,000. The draught of the vessel is 5 feet. The Yarrow boilers worked very satisfactorily during the trial.

Sunfish.—This topedo boat destroyer, the preliminary trial of which was given on page 822 of Vol. VII, completed her three hours' official trial on January 15, with the following average results:

Steam pressure in boilers, pounds per square inch	188
Revolutions per minute	351.2
I.H.P.	4,174
Speed, knots	27.581

The mean speed for six runs over the measured mile at the Maplin was 28.082 knots. The above results were easily obtained and the coal consumption was moderate.

Zebra.—This torpedo boat destroyer was launched on December 3, 1895, from the Thames Iron Works. The principal dimensions are as follows:

Length betwween perpendiculars, feet	200
Beam, feet	20
Draught, load, feet	6
Displacement, tons	303
Speed, knots	27

The armament consists of one 12-pounder gun on the conning tower, five 6-pounders and two torpedo tubes.

The machinery was built by Messrs. Maudslay, Sons & Field. There are two inverted four-cylinder triple-expansion engines, which are to indicate 4,500 H.P. when making 380 revolutions per minute. The stroke is 18 inches. The water tube boilers, also built by the Messrs. Maudslay, are of Mr. J. S. White's patented type. The three boilers have a total heating surface of 11,250 square feet, the working pressure being 225 pounds per square inch. Forced draft will be used.

This vessel is a sister ship to the *Conflict*, *Teazer* and *Wizard* building at Mr. White's yard, at East Cowes, Isle of Wight.

Thrasher and Virago.—The last two of the four 30-knot

torpedo boat destroyers building by Messrs. Laird Bros., Birkenhead, were launched on November 5 and 19, respectively.

Desperate.—The following description has been taken from "Engineering," London:

This is one of the six new torpedo boat destroyers that have been ordered by the Admiralty from Messrs. John I. Thornycroft and Company, of Chiswick, two of these vessels having, within the last few days, been added to the original four which were entrusted to the Chiswick firm to construct. The names of the first four are *Desperate*, *Foam*, *Fame* and *Mallard*. The other two are not yet named.

These vessels are 208 feet long on the water line, or 210 feet long over all. The maximum breadth is 19 feet 6 inches, and the depth 13 feet 6 inches. In general design the new boats follow the *Daring*, the first destroyer built by Messrs. Thornycroft, very closely, the chief alteration being the larger size of the more recent vessels, whilst to attain the higher speed bigger engines and boilers have been introduced. The points in which the *Desperate* and her sisters depart from the original design are as follows:

The additional three knots, in excess of the 27 knots before guaranteed, is to be obtained chiefly by putting in more power. The relative weight of hull has, however, been reduced where possible, the most important feature in this direction being the use of a new special steel which has been manufactured especially for these boats. It has a tensile strength of 38 to 43 tons per square inch, and the extension is 15 per cent. on a 10-inch specimen. This may be compared to the 28 tons of the usual mild steel. It should be stated that the additional strength and stiffness—the latter being a very important feature—is not obtained by higher carbon, but by a new alloy, made specially for these vessels, in which strength and ductility are combined. In this way the scantling has been reduced without sacrifice of the strength of structure.

In regard to the interior arrangements, the design of the *Daring* has been followed. The boat's complement is 56 all told. The officers' quarters are right aft, whilst the crew are berthed,

some right forward, and others just aft of the machinery space and next to the officers' quarters. It is certain that the officers have the most uncomfortable part of the vessel, getting all the vibration from the propellers. The forward part is undoubtedly the most comfortable, the turtle back deck in the bow giving a chance to make a good lofty cabin.

The armament also is much the same as in the *Daring*, but there are two more 6-pounder guns, or five in all, and only two torpedo tubes in place of three, the *Desperate* and her sisters having no bow discharge. Only six of these destroyers have the bow tubes, namely, the *Daring*, *Decoy*, *Havock*, *Hornet*, *Ferret* and *Lynx*. The general opinion of naval authorities appears to be in favor of reducing the torpedo equipment of these vessels in favor of the gun armament. It is said that destroyers should be destroyers, and not torpedo boats. On the other hand, it is claimed by some that so long as the destroyers have the speed and gun power requisite to give them certain victory over the torpedo boat, there can be no harm in giving them powers of offence against larger vessels. The argument is a little dangerous, because one destroyer might find herself opposed by several torpedo boats, and she would then want all the guns she could carry; moreover, an enterprising commander would be likely to have a keener desire to bag big game, and might be apt to forget his proper function of protecting the fleet by destroying the little craft of the enemy.

Another new feature in the later destroyers is a commander's bridge or platform forward, just abaft the conning tower. Here there is a steering wheel, and the larger size of these boats makes the position tenable even in bad weather. The advantages of handling a boat in the open rather than through a conning tower will be apparent.

The form of bow adopted by Messrs. Thornycroft in the *Desperate* is different, as the stem, in place of raking aft from the water line, slopes forward. The object is to make the boat drier when steaming at speed. One of the chief troubles anticipated in action with these very fast boats is the heavy spray that is knocked up just at the point where the stem meets the water.

This spray mounts up the sides of the bow and rushes aft in a torrent that would prevent the effective handling of the forward gun. Especially when steaming to the wind this is a very serious matter, and if there be anything more than a smart breeze, it is almost impossible to look out ahead. It is not a question of "green water" coming on board and danger to the vessel, it is simply that the drops of water drive aft and cut like hail. In order to meet this, Messrs. Thornycroft have modified the cutwater in the manner described. The point where the stem meets the water is several inches—perhaps 2 feet—aft of the extreme end of the deck. The water that runs up the side, owing to the sudden momentum it acquires by being struck by the boat, has, as it were, a more overhanging wall to climb instead of one more approximately vertical, and is, therefore, more likely to fall back than get over the top. To increase this effect the designer has given the *Desperate* more flare than usual, a feature which makes the vessel appear somewhat full forward. On the water level, however, the lines are extremely fine forward, and the stem itself is brought almost to a knife-edge. To judge by the form of the *Desperate*, as she lies at present on the stocks, she is likely to prove very successful in the matter of dry decks, and her design bears evidence of that combination of boldness and true appreciation of the needs of the situation which has always distinguished the work turned out at Chiswick from the days of the *Ariel* down to the present time.

The other end of the boat is also unusual, though no longer novel. It consists of what is known as the Thornycroft stern. The bottom of the boat, right aft, in place of being of the usual ship form, slopes up to the water level, which it meets at the sternmost part. As the width is carried well to the end, this would give a flat floor, but with the Thornycroft stern the floor is more than flat; it is absolutely arched upwards. It has been usual to give a rounded corner where the floor joins the sides, but a small alteration has been made here, the bottom plating right aft being absolutely carried out level, and ending in a sharp edge. The result is what may be described as an arris—to borrow a non-nautical term—and an easier delivery is given to the wake. The

finish looks a little ragged, but there is no doubt it is an improvement, as there was a certain amount of eddying at the rounded corners, and although this might be inappreciable under ordinary circumstances, at the enormous speed these boats travel it is apparently worth considering. Whilst speaking of the Thornycroft stern we may allude to a fact which has recently come to our knowledge. It appears that the Newhaven and Dieppe boat, *Tamise*, has this form of after body, there being, however, only one rudder in place of the two always fitted by Messrs. Thornycroft. We understand that the *Tamise* in bad weather makes her passage in an hour less time than she would do if she had the ordinary stern, the speed being estimated by taking a line through the performances of other boats built in the usual manner. Probably the comparatively fast steaming the *Tamise* keeps up in bad weather, is due to the position of the screws under the stern of the boat, an arrangement which prevents racing in rough water. The same remark, of course, applies to the vessels built by Messrs. Thornycroft, the cross-channel boat being similar to the Chiswick craft in this respect.

The machinery of the *Desperate* is similar to that of the *Daring*, only a few unimportant changes having been made in the arrangement. The proportions of both boilers and engines have been enlarged, and the grate and heating surface increased. The cylinders of the triple-expansion engines are now 20 inches, 29 inches and two of 30 inches diameter, the stroke being 18 inches. Of the three boilers, the two forward ones are placed back to back, and have a smoke pipe in common, whilst the after boiler has one to itself. The forward smoke pipe has naturally a larger cross-area than the other, but the smoke pipe casings are made of the same size, so that in appearance both pipes are alike in size. The annular space between the after smoke pipe and its casing is made to serve as an upcast shaft, by means of which the engine room is ventilated. This arrangement has been found by experience to work very well in practice, a comparatively cool engine room being thus secured—no small advantage in the confined space full of high pressure steam pipes, &c., with which these boats are crowded.

Thirty-knot Torpedo Boat Destroyers.—Contracts for twelve more of these destroyers, twelve of which were named on page 820 of Vol. VII, have been awarded as follows:

Two to the Naval Construction and Armaments Company, Barrow-in-Furness. These will be fitted with Thornycroft boilers.

Two to the Fairfield Ship Building and Engineering Company, Govan. These will be fitted with Thornycroft boilers.

Six to the Palmer Ship Building Company, Jarrow. These will be fitted with Reed boilers.

Two to Messrs. Thornycroft & Co., Chiswick. These are in addition to the four now building by them, and described above, and will, of course, be fitted with their own boilers.

Some interesting information in regard to the bids for the destroyers, mentioned in the last number of the JOURNAL, has been published.

Messrs. Thornycroft & Co. offered to build three destroyers at $277,500 each (at $5 to the pound sterling), and Messrs. Yarrow & Co. three boats at $272,100 each. The Admiralty did not accept these bids, but offered Messrs. Thornycroft & Co. three boats at $257,500 each, and Messrs. Yarrow & Co. three at $252,100. Messrs. Yarrow & Co. refused this offer, and then the Admiralty raised its offer to $257,500 per boat, but this was again declined.

FRANCE.

Brennus.—This battleship, launched on October 17, 1891, and which is one of those in which extensive changes have been made on account of instability, has been having her final trials.

The general dimensions and a short description of this vessel were given on page 806 of Vol. VI of the *Journal*. The designed displacement was about 10,826 tons.

During the trials in August, 1894, when the increase in displacement of 396 tons corresponding to an increase of 9″ in draught was discovered, it was also found that when steaming 15.3 knots and the helm was put over 10 degrees, the angle of keel was 9° 30′, exposing the unarmored part of the hull on one side, the top of the armor belt on the other side being under water. The top of this belt was supposed to be two feet above water. Besides

this grave defect, it was also found on trial in port that with the above angle of inclination, the hydraulic gear could not turn the turrets and guns, as the greatest angle at which these could be worked was 5°15′. The defects of instability and displacement were removed by cutting down the superstructure and taking out the after military mast with its tops.

When the alterations were completed the ship started on her trials, October 12, 1895. The first trial was stopped, soon after its commencement, by the heating and melting of several connecting-rod brasses, the engines making at the time 88 revolutions, the approximate speed being a little over 17 knots. After these defects were made good, the trials were resumed on November 18, the speed attained being 18.2 knots with full power and 92 revolutions per minute. The deck forward was driven in by the force of the water and the ship had to return to port. After repairs, on January 9, 1896, a four hours' trial was nearly completed. The speed realized was 17.3 knots. Towards the end of the trial one of the crank pins of the port engine heated so much that the engine had to be stopped. The heat in the fire rooms was excessive, reaching 152° F. at times.

The engines are of the vertical, inverted, four-cylinder, triple-expansion type and were built at the naval arsenal at Indret. There are 32 Belleville boilers with a total grate surface of 1,100.5 square feet and a lotal heating surface of 35,030.8 square feet.

Henri IV.—This vessel, formerly designed to be a sister of the *Charlemagne* and *St. Louis*, is to be laid down at Cherbourg under the appropriation for 1896 as a coast defense vessel of our monitor type. The principal characteristics are as follows:

Length, feet	278.8
Beam, feet	65.62
Displacement, tons	6,889
I.H.P	6,904
Speed, knots	15
Radius of action at 10 knots, nautical miles	6,000

The armament will consist of one 12-inch gun, ten 5.43-inch guns, six of these to be rapid fire guns, two mortars (?) of large

caliber mounted forward, eight 1.85-inch rapid fire guns and two machine guns.

The total cost of the vessel is estimated at about $3,135,815.

Jeanne d'Arc.—This first class, triple-screw, armored cruiser is to be laid down in one of the naval dockyards under the appropriation for 1896, and takes the place of the cruiser previously designed as "D_2." The following description has been published:

Length, feet	469.2
Displacement, tons	10,826
I.H.P., about	27,616
Speed, knots	23

There will be an armor belt 5.91 inches thick, its top being 2.3 feet above the water line. The protective deck will be 2.16 inches thick.

The armament will consist of two 7.48-inch guns and eight 5.51-inch, twelve 3.94-inch, sixteen 1.85-inch and eight 1.46-inch rapid fire guns and two Maxim machine guns.

The maximum coal supply will be sufficient for a steaming radius of 15,000 nautical miles at 10 knots.

Du Chayla.—This protected cruiser, described on page 204 of Vol. VI, is of the *Bugeaud* type slightly enlarged, and was launched at Cherbourg, on November 18, 1895. The principal dimensions are

Length, between perpendiculars, feet	325.6
Beam, feet	44 9
Depth, feet	29.8
Draught, aft, feet	20.5
mean, feet	19.0
Displacement, tons	3,888
I.H.P., under forced draft	9,370
Speed, knots	19.25

The protective deck has inclined sides, 3.15 inches thick, and a flat top, 1.2 inches thick. The cofferdam along the water line is filled with cellulose.

The armament is the same as that of the *Bugeaud*, namely: six 6.3-inch and four 3.94-inch rapid fire guns, several 1.85 and 1.46-inch guns and two torpedo tubes.

There will be twin-screw vertical triple-expansion engines and twenty d'Allest water-tube boilers placed in three compartments.

The coal capacity is about 600 tons. The complement will be 14 officers and 371 men. The total cost is estimated at $1,579,176.

Pascal.—This sheathed second class cruiser, the keel of which was laid December 4, 1893, was launched at Toulon on September 26, 1895. The following particulars are now available:

Length, feet	315.9
Beam, feet	42.25
Draught, forward, feet	16.92
Draught, aft, feet	20.73
Displacement, tons	3,925
I.H. P	8,384
Speed, knots	19

The protective deck is 1.97 inches thick on the inclined sides and 1.38 inches on the horizontal part. On top of this deck, and extending the whole length of the vessel, are numerous compartments, some of which are filled with coal.

The double bottom extends the whole length of the vessel.

The armament consists of four 6.3-inch, ten 3.94-inch, fourteen 1.85-inch and eight 1.46-inch rapid fire guns and one torpedo tube on each broadside. The battery is so arranged that, when chasing, two of the 6.3-inch and six of the 3.94-inch guns can be fired directly ahead.

The engines are twin-screw, triple-expansion, and were built by the Chantiers de la Loire. The sixteen Belleville boilers are equally divided in four compartments. These boilers are tested to 242 pounds per square inch. The usual coal supply is 551 tons.

Protet.—This sheathed second class cruiser will have the following dimensions:

Length, feet	332
Beam, feet	44.62
Displacement, tons	4001

The armament will consist of four 6.49-inch, ten 3.94-inch, ten

1.85-inch and four 1.46-inch rapid fire guns, and two above-water torpedo tubes.

The engines will be vertical, triple expansion, and will be of 8,877 I.H.P. The designed speed is 19 knots.

Jurien-de-la-Graviere.—This sheathed cruiser will be almost identical with the preceding *Protet*, the only difference being in the beam, which is increased to 45.93 feet.

D'Estrées, Infernet and K3.—These three third class cruisers will be sheathed. Their principal dimensions are:

Length, feet	265 7
Beam, feet	37·73
Draught, feet	17 22
Displacement, tons	1,968

The armament will consist of four 5.45-inch, five 2.56-inch and six 1.46-inch rapid fire guns. There will be no torpedo equipment.

The I.H.P. of the twin-screw engines will be 4,142, the designed speed of vessel being 17 knots. The boilers will be of the D'Allest type.

Dunois and **La Hire.**—These two torpedo boat destroyers, or torpedo despatch vessels, are of a special design by Mr. Trogneux, their large size fitting them for use under all conditions of weather and sea. They will be laid down at Cherbourg under the appropriation for 1896. The principal characteristics are:

Length, feet	254.6
Displacement, tons	886
I.H.P.	6,411
Speed, knots	23

There will be hard steel plates at the water line abreast of the machinery spaces, the deck above these spaces being similarly protected.

The armament will consist of six 2.56-inch and six 1.85-inch rapid fire guns.

The total cost of each destroyer is estimated at about $616,920. They will be fitted with Normand boilers.

Kersaint and ———.—These cruisers, the first of which is building at Rochefort and the second to be laid down at Toulon, have the following dimensions :

Length, feet	225.2
Beam, feet	34.45
Displacement, tons	1,223

The armament will be one 5.43-inch, five 3.94-inch and seven 1.46-inch rapid fire guns.

The I.H.P. will be 2,170 and the speed 15 knots.

Cassini.—This torpedo cruiser, the preliminary trials of which were noted on page 430 of Vol. VII, has made several attempts at her full power trial. In August, 1895, a propeller blade broke. Another attempt was made in November, but at the end of one-half hour one of the eccentrics heated and the eccentric strap broke. The vessel was laid up for repairs about one month, after the completion of which, another attempt was made in December.

After running 22 of the 24 hours' trial satisfactorily, a blade of one of the propellers broke. The vessel returned to Cherbourg and was docked. The four blades of each propeller are of bronze, secured to a steel hub.

The contract speed is 21.5 knots, the vessel being liable to rejection if the speed falls below 20 knots.

Aquilon, sea-going torpedo boat. The contract for this boat was let to Mr. Normand at Havre on July 12, 1893, but owing to stinted appropriations its construction was so much delayed that the launch did not take place until December 10, 1895. The following description is taken from "Le Yacht," Paris:

Length, feet	137.8
Beam, feet	14 76
Depth, feet	9.84
Draught of water under propellers, feet	7.87
hull, aft, feet	4.26
mean, feet	4.43
Area of midship section, square feet	45.96
Displacement, tons	118.1
I.H.P. at 25 knots	1,973
23.5 knots	1,677
14 knots	345

The armament consists of two 1.85-inch rapid fire guns and two torpedo tubes. Four torpedoes are carried.

There are eight transverse water tight bulkheads. There are two rudders, one at each end, the after rudder being abaft the propellers.

The engines are twin-screw, triple-expansion and are to develop the maximum power when making 350 revolutions per minute. The weight of engines and boilers is 50.2 tons.

The boilers are tubulous of the Normand type and have been tested to 213 pounds per square inch.

The coal capacity is 15¼ tons.

The contract price is $115,000, with a premium of $400 for each tenth of a knot above the maximum speed of 25 knots. If the speed on trial is less than 23.5 knots, the boat will be rejected. The principal trials are to consist of an eight hour run at 14 knots, a six hour run at 21 knots, and runs over the measured mile, during which a mean speed of 25 knots is to be attained.

There is one dynamo of 80 volts and 50 amperes, which supplies the current for twenty 10-c. p. incandescent lamps and a search light, 15¾ inches in diameter. There are besides, eight accumulators of 70 ampere-hours (at 10 amperes).

A comparison of the contract price of this boat with that of the *Flibustier* and *Forban* (both described on page 825 of Vol. VII) shows that the *Flibustier*, with a maximum requirement of 23.5 knots cost only about $13,400 less than the *Aquilon*, with a maximum requirement of 25 knots, while the *Forban*, with a maximum requirement of 30 knots, cost over twice as much as the *Aquilon*.

Thenard.—This 30-knot sea-going torpedo boat of the *Forban* class, and two first class torpedo boats, will be built by contract under the appropriation for 1896.

GERMANY.

Geier, formerly F.—This third class cruiser, of which general dimensions were given on page 808 of Vol. VI, has completed her speed trials. The average I.H.P. developed was 2,910 and the mean speed attained, 17 knots.

The pitch of the propellers is to be altered and further trials made.

HAYTI.

Crête-à-Pierrot.—This single-screw cruiser was launched on November 7, 1895, by the Earle's Shipbuilding and Engineering Co., Hull. Her displacement is 1,000 tons. She has a flush upper deck, poop, topgallant forecastle, and a complete lower deck. The bow terminates with a cast-steel ram, and the stern is elliptic in form. The poop is fitted up with accommodation for the admiral and superior officers. The 'tween-deck space is fitted for the junior officers, armory and steering compartment, and below these are store-rooms, magazines and shell-rooms. The bunkers extend the whole length of the engine and boiler spaces and form a side protection to the machinery and boilers. The vessel is very fully subdivided into water tight compartments, and water tight doors are fitted only where absolutely necessary. A very complete system of pumping, drainage and ventilation is being carried out for all living spaces, stores, coal and machinery compartments; there is also a complete installation of electric light, including a search light. The vessel will have a light fore-and-aft rig, with trysails and gaff-topsails. There will also be a full complement of boats, including a steam launch. Steam steering gear is fitted amidships, with well protected leads to the tiller aft, and to the steering stations in the wheel house and in the steel rifle-proof conning tower. The armament will consist of one 6.3-inch gun on the forecastle, one 4.7-inch gun on the poop, and four 3.94-inch guns in sponsons on the broadside, all rapid fire guns. In addition there are two Maxim and four Nordenfeldt machine guns fitted on the forecastle, bridge, and near the gangways. The vessel has fine lines, and will be propelled by a powerful set of vertical triple-expansion surface-condensing engines, capable of driving her at a high speed. She has also a very complete set of auxiliary machinery. Sir E. J. Reed prepared the designs and superintended the construction of the ship.

HOLLAND.

Piet Hein.—This coast defense vessel, a short description of which was given on page 808 of Vol. VI, has had her trial. The following particulars, and the result of the trial are now available:

Length over all, feet and inches	282–9
between perpendiculars, feet and inches	267–7½
Breadth, extreme, feet and inches	46–10½
Depth, moulded, feet and inches	26–10½
Draught, forward and aft, feet and inches	16–9
Immersed midship section, square feet	708
Displacement, tons	3,400
Coal on above displacement, tons	250
I.H.P. for four hours	4,736
Speeds, knots (about)	16
Area of load water line plane, square feet	8,900
L.W.L., coefficient	.681
Coefficient of fineness, prismatic	.571
Midship section, coefficient	.920

The engines are of the twin-screw, vertical, triple-expansion type, with cylinders 27, 40 and 63 inches in diameter, and a stroke of 27 inches. The cylinders are steam jacketed all over. There is a piston valve on the H.P. and slide valves on the I.P. and L.P. cylinders, all operated by Stephenson link motion. The connecting and piston rods are hollow, the latter 5¾ inches in diameter, with a 3-inch hole. The crank shaft is in two sections, 11 inches in diameter, with a 5-inch axial hole, and the pins 11¼ inches diameter. The condensers are cylindrical and have a combined cooling surface of 6,018 square feet. The circulating pumps are of the centrifugal type, with runners 3½ inches in diameter.

The air pumps are worked from the L.P. crossheads, and are 26 inches in diameter and 9 inches stroke. The boilers are four in number, cylindrical, placed back to back, and were designed for a working pressure of 180 pounds per square inch. They are 13 feet 2 inches in diameter and 12 feet 3 inches long, each with three Purves' ribbed flues, 40 inches inside diameter, and three combustion chambers. The total grate surface is 240 square feet, and the heating surface 9,084 square feet. Forced draft is on the Howden system. The boiler tubes are of brass and of the Serve patent.

The propellers are four-bladed, of Delta metal, and are 11 feet 6 inches in diameter, and have a pitch adjustable from 12 to 15 feet; the blades were set at 12 feet 9 inches for the trial. Surface of blades of each screw, 43.3 square feet.

The weight of machinery, including water in boilers and condensers, is 424 tons.

On trial she was loaded to a mean draught of 16 feet 9 inches. Her speed was a trifle above 16 knots, the engines making 149.45 revolutions per minute.

ITALY.

Sicilia.—This battleship, which was launched July 6, 1891, and a general description of which was given on page 604, Vol. III, had her official trials on September 19, 1895.

The general features of the design are here repeated. Length between perpendiculars, 400.3 feet; beam, 76.8 feet; mean draught, 28.7 feet; displacement, 13,090 tons; I.H.P., 19,500, forced draft; speed, 18 knots.

In the following table the results of the *Sicilia's* trials are compared with those of the sister ship, the *Re Umberto*, the trials of which were described on page 207 of Vol. VI.

The machinery of the *Sicilia* was built by Messrs. G. Ansaldo & Co., Sampierdarena, Genoa, and that of the *Re Umberto*, by Messrs. Maudslay, Sons, & Field, England.

The trials consisted of a run of six hours' duration, and progressive speed trials over the measured mile, both ships going over practically the same course:

Natural draft trial.	*Sicilia.*	*Re Umberto.*
Duration, hours	6	6
Displacement, tons	13,164	.....
Draught, forward, feet	28.31	.....
aft, feet	28 97	.....
Steam pressure, mean, pounds per square inch	91	.....
Revolutions, per minute	.....	95
I.H.P., mean	15,288	17,000
Speed, mean, knots	19.2	18.3
Air pressure, inches	0	½

The maximum I.H.P. developed on this trial by the *Sicilia's* engines was 16,669, the corresponding speed being 19.6 knots.

On the progressive trials over the measured mile, the following results were obtained:

	Sicilia.	*Re Umberto.*
Draught, mean feet	28.64	29.36
Displacement, tons	13,164	13,607
Revolutions, per minute	85 about.	91
I.H.P.	15,000 about.	17,014
Speed, knots	19	19

As a result of these trials, the pitch of the propellers of the *Re Umberto* was increased to that of the propellers of the *Sicilia*.

Ammiraglio Saint Bon and **Emanuele Filiberto.**—These two battleships are under construction, the former at Venice and the latter at Castellamare. The following are the principal particulars:

Length, feet	344.5
Beam, feet	69.39
Draught, mean, feet	24.25
Displacement, tons	9,666
I.H.P. forced draft	13,315
Speed, knots	18

There will be a water line belt of nickel steel 9.84 inches thick. Above this, and extending about two-thirds the length of the vessel, is a 5.9-inch belt which encloses the base of the turrets. The central battery, on the same level as the turrets, is above this, and is protected by the same thickness of armor. The protective deck ranges from 1.57 to 3.15 inches in thickness. The two turrets will have 10-inch nickel steel armor, and the conning tower and ammunition tubes, 6-inch armor. The armor will be made by the Terni works.

The armament will consist of two 10-inch guns in each turret, eight 6-inch rapid fire guns in the casemate and separated from each other by steel splinder bulkheads, eight 4.7-inch and six 2.24-inch rapid fire guns on the superstructure and several machine guns. Two torpedo tubes will be fitted on each broadside and one in the stern. The guns will be built by the Italian

branch of the Armstrong firm at Puzzuoli. The twin-screw engines will be built by the Messrs. Ansaldo & Co., Genoa. There will be twelve cylindrical boilers, in four separate compartments, the working pressure being 155 pounds per square inch. The furnaces will be fitted to burn liquid fuel besides coal. The maximum coal supply will be about 1,000 tons, and the complement of officers and men 600.

Umbria.*—The following particulars are additional to the data given on page 809 of Vol. VI:

The designed load displacement was 2,244 tons.

The propellers are of the Griffith type.

The diameter of the two after boilers is 13.12 feet, the diameter of the two forward boilers being 12.3 feet. The grates of the two after boilers are 6.04 feet long by 3.2 feet wide, and of the two forward boilers, 6.04 feet by 2.94 feet.

The weight of machinery is 631 tons.

The coal consumption during the natural draft trials was 1.64 pounds per I.H.P per hour, well under the maximum margin of 2.01 pounds specified in the contract. On the forced draft trials, the coal consumption was 1.81 pounds per I.H.P. per hour.

The results of progressive trials made on the measured mile, beginning with forced draft and going down to 70 revolutions, are shown in the table. The ship's bottom was clean; the displacement, 2,247 tons, with a mean draft of 15 feet; the mean pitch of propellers, 15.88 feet. Four boilers were used during all the trials.

Draft.	Forced.	Natural.	Natural.	Natural.	Natural.
Steam pressure in boilers, pounds per square inch...	140	138	135	135	130
Cut off in H P. cylinders....	0.65	0.52	0.65	0.65	0.65
Number of revolutions per minute.....	148	127	110	90	70
I.H.P.	7,298	4,842	2,959	1,795	621.4
Speed, knots.....	19 0	17.7	15.5	13 0	10.3

*(The data of the progressive trials of the *Umbria*, *Lombardia*, *Etruria* and *Liguria* are from the "Mittheilungen aus dem Gebiete des Seewesens."—EDIT.)

Lombardia.—On the progressive trials of this cruiser, the results of which are tabulated below, the hull was clean, the vessel had 177 tons of coal on board and her normal equipment, the displacement being 2,342 tons, with a mean draught of 15.58 feet. The mean pitch of the propellers was 15 feet.

Draft.	Natural.			Forced.
Number of boilers in use	2	2	4	4
Steam pressure in boilers, pounds per square inch	125	125	140	140
Cut off in H P. cylinder	0.5	0.6	0.7	0.8
Number of revolutions per minute	40	79	116	149
I.H.P.	172.6	805.8	2574	5,927.5
Speed, knots	5.3	10 6	15.0	18.4

Etruria.—The following table gives the results of progressive trials of this cruiser. The vessel had 177 tons of coal and about 13.8 tons of reserve water for boilers on board and was fully equipped, her displacement being 2,264 tons, with a mean draught of 15.22 feet. The mean pitch of the propellers was 15.74 feet. The trials lasted two days and were begun with the lowest number of revolutions per minute.

Draft.	Natural.					
Number of boilers in use	2	2	2	2	2	2
Steam pressure in boilers, pounds per square inch	145	140.1	130 1	140.1	150.2	150.2
Cut off in H.P. cylinder	0 43	0 43	0 43	0.43	0.43	0.43
Number of revolutions per minute	39.5	48	59	69.4	78.6	89
I.H.P.	202 2	300 8	512.9	715	1,008	1,443
Speed, knots	5.6	6 9	8.5	10.0	11.5	12.85

Draft.	Natural.				Forced.
Number of boilers in use	4	4	4	4	4
Steam pressure in boilers, pounds per square inch	115	120 2	118.9	143	152.2
Cutt off in H.P. cylinder	0.65	0.65	0.65	0.65	0.65
Number of revolutions per minute	100.5	105 5	113 5	126	142
I.H.P.	1,988	2,396.5	3,145	4.538.5	6,922
Speed, knots	14.0	14.9	15.7	16.9	18.8

Liguria.—The progressive trials of this vessel consisted of two runs over the measured mile at 40, 50 and 60 revolutions, and one run at 70 revolutions, followed, a few days later, by two runs each at full power under natural and forced draft, and then runs at 120, 105, 90 and 75 revolutions.

On the full power runs, the vessel had on board 256 tons of a poor quality of coal, 19.7 tons of reserve water for boilers, about 8 tons of ballast, and 12.8 tons of water in the double bottoms. The 20.8 tons of ballast and water were added, as some of the guns and shields had not been put on board. The displacement was 2,214 tons, with a mean draught of 14.92 feet. The mean pitch of the propellers was 13.51 feet.

The results of the progressive trials are given in the table in the order of revolutions:

Draft.	Natural.									F'rc'd
No. of boilers in use...	2	2	2	2	4	4	4	4	4	4
Steam pressure in boilers, lbs per sq. inch	150 2	150.2	145.9	145.2	150.2	140.1	142.1	138.2	143.1	142.1
Cut off in H P. cyl.....	0.2	0.2	0.2	0.2	0 2	0.2	0.2	0 2	0.3	0.4
No. of revol per min..	39	49.5	60	69.5	73 4	89	105	119	127	145.4
I.H P.....	144	219.9	417.2	571.	653.8	1127 2	1908.3	4905 4	3392 8	5459.5
Speed, knots.....	5.1	6.3	7 6	9.1	9.5	11.3	13 25	14.9	15.9	18.1

Agordat and **Coatit.**—These two protected torpedo cruisers, a larger and faster *Partenope* type, were designed by N. Soliani and are to be built at Castellamare. The principal dimensions are:

Length, feet	287.4
Beam, feet	30.51
Draught, aft, feet	11.08
forward, feet	9.94
at middle, feet	10.51
Displacement, tons	1,292

They will be built of steel, with a protective deck 3.28 inches thick on the flat and 6.56 inches thick on the sloping sides. The coffer dams above the sloping part of the protective deck will be used as coal bunkers.

These two cruisers are expected to be the fastest in the Italian navy.

NORWAY.

Torpedo Boats.—The contract for three torpedo boats has been let to the lowest bidders, Messrs. Schichau & Co., Elbing, Germany. These boats are to have a displacement of 95 tons and a speed of 23 knots. They are to be delivered in ten months, the price for each being about $50,000.

RUSSIA.

Pereswich and **Oslabya.**—These two armored cruisers are building at the Baltic Works, St. Petersburg. The general dimensions are as follows:

Length, feet	436.4
Beam, feet	72.18
Depth, feet, about	26
Displacement, tons	12,795
I.H.P., about	14,500
Speed, knots	18

The armament will consist of four 9.84-inch guns, eight 6-inch guns on the upper deck and well protected, six 4-72-inch guns, and several of smaller caliber, and six torpedo tubes.

Svetland.—This protected cruiser, building at Havre, a general description of which was given on page 607 of Vol. VII, has been named.

The first rivet was driven on December 7, 1895.

Khrabry.—This gunboat was launched on November 21, 1895, from the Naval Arsenal at St. Petersburg. The general dimensions are

Length on water line, feet, about	229
Beam, feet and inches	41–7
Draught, feet	11
Displacement, tons	1,492
I.H.P.	2,000
Speed, knots	15

Her armament will consist of one 9-inch, one 6-inch, and eight rapid fire guns.

Vierny.—This training corvette is composite built and was

launched on November 21st, 1895. The principal dimensions are:

Length, feet	223
Beam, feet	36
Draught, feet and inches	13·6
Displacement, tons	1,290
I.H.P	500

The armament consists of six four-pounders and some smaller rapid fire guns.

The boilers are of the Belleville type.

The sail area is 13,000 square feet.

Torpedo Boat Destroyer.—A contract was recently given to Messrs. Creighton, Abo, Finland, for a destroyer of the same type as the *Sokol*. The new vessel is to be 240 feet long.

SPAIN.

Carlos V.—The following additional particulars of this cruiser, which was described on page 434 of Vol. VII, are from "Engineering," London:

She was built at Cadiz, in the shipyard of Veamurgia Hermanos, and was launched on March 12 last. The vessel displaces in sea-going trim 9,089 tons, her draught being then 24 feet forward and 26 feet aft. The hull is built of Siemens-Martin steel, and there is side armor 2 inches thick, 1 inch of Siemens-Martin steel and the other 1 inch of chrome steel. The protective deck is of steel, the maximum thickness being 6⅛ inches, made up of three plates.

The armament consists of two 11.02-inch Hontoria guns, ten 5.51-inch Hontoria quick firing guns, four 3.94-inch and two 2.76-inch quick firing guns, four 2.24-inch and four 1.46-inch Nordenfeldt guns, two machine guns (mitrailleuses), and six Schwartzkopff torpedo tubes.

The twin-screw triple-expansion engines were constructed at the well known engineering establishment of La Maquinista Terrestre y Maritima of Barcelona, under the able direction of Senor Don Ernesto Tous, and from designs prepared and supplied by Messrs. Maudslay, Sons, and Field, England. The

engines are of the inverted type, with four cylinders—one high-pressure, 52 inches in diameter, one intermediate, $77\frac{3}{16}$ inches, and two low pressure, $82\frac{3}{32}$ inches in diameter, each adapted for a $45\frac{5}{16}$-inches stroke; at 100 revolutions they develop 18,500 horse-power. Each cylinder is supported on four cast-iron standards, having cast-iron crosshead guides bolted on their faces. The high-pressure cylinders have piston valves, and the intermediate and low have double-ported slide valves, all of which are worked by links and double eccentrics. The piston-rods, connecting rods, and shafts are of steel, each crankshaft being made in four pieces, interchangeable. The main condensers, two in number, are of gun-metal, and have horizontal tubes $\frac{3}{4}$ inch in diameter, through which the circulating water passes. The total cooling surface is 22,500 square feet. There are four vertical single-acting air pumps, 30 inches in diameter by 21 inches stroke, which are worked by beams from the cylinder crossheads.

The propellers are of gun-metal, 18 feet 6 inches in diameter and 24 feet pitch, and are fitted with four blades each.

There are 12 single-ended cylindrical boilers, 16 feet $3\frac{3}{8}$ inches in diameter by 9 feet $10\frac{1}{8}$ inches long, having 48 furnaces, 3 feet $8\frac{1}{2}$ inches in diameter. The total area of fire grate is 1,246 square feet. The tubes are $2\frac{1}{2}$ inches in diameter and 7,080 in number, and have a surface of 32,241 square feet. The total heating surface is 36,825 square feet.

Torpedo-boat Destroyers.—Messrs. J. and G. Thompson of Clydebank have been awarded a contract to build two sea-going destroyers. The sea speed is to be 28 knots with a load of 75 tons on board.

U. S. OF COLOMBIA.

General Nerino.—This is the name given to the gunboat building by Mr. H. Ramsay, and described on page 841 of Vol. VII. The steel covered conning tower or pilot house is not on the military mast, but is situated forward of it and close to the bow.

There will be one Roberts' water tube boiler with a working pressure of 200 pounds per square inch. Induced draft will be used. There is one smoke pipe.

The boiler is 9 feet wide athwartships, 8 feet long fore-and-aft, and 7 feet 6 inches high, exclusive of ash pit. It will be tested by hydrostatic pressure to 500 pounds and to 250 pounds by live steam pressure before leaving the works, and the coils will be tested to 600 pounds before incorporation into the boiler. It has an unusually deep fire box for burning the wood found along the rivers where the vessel is to be used. It is anticipated that the boiler will generate sufficient steam for about 430 H.P. with natural draft. The weight of the boiler will be approximately 16,000 pounds, without water, ash pan, or smoke pipe.

MERCHANT STEAMERS.

Curacoa.—This is the name of the steamer built by Messrs. Cramp for the Red D line, and a few particulars of which were given on page 436 of Vol. VII. The following description is from the "Marine Journal," New York.

The *Curacoa* was built at Cramp's yard, Philadelphia, from the design of John Haug. She was launched there September 30 and registered at Wilmington, Del., by the Atlantic and Caribbean Steam Navigation Company. She was designed especially for the freight and passenger service between New York and Maracaibo in the fleet conducted by Messrs. Boulton, Bliss & Dallett of New York, and was built to carry a large cargo on a light draught in order to go over the bar at Maracaibo, which few ships of her tonnage can manage. Consequently her greatest draught will not much exceed ten feet, while her tonnage is 1,503.44 gross and her cargo capacity is about 75,000 cubic feet. Her construction was in accordance with the requirements of the government for steamers of the fourth class mail subsidy and her speed is twelve knots, while she has received the highest classification in the Record of American and Foreign Shipping. Her dimensions are: Length over all, 256 feet; beam, moulded, 38 feet 5 inches; depth, 17 feet. The hull has been constructed throughout of the best quality tested American steel, with high bulwarks and steel deck houses on the main deck. There are five water tight bulkheads. The water ballast tanks have a capacity of 200 tons. The engines are of the triple expansion type, having cylinders 18, 28 and 45 inches in diameter, with a stroke of 32 inches. The boilers furnish steam at a working pressure of 160 pounds. All of the machinery fittings are of the most approved type. Independent circulating and air pumps, an ash hoist, evaporator, grease extractor, etc., are provided.

The passenger accommodations are superb and designed especially for the tropical trade, there being no upholstering to get stuffy and everything being as airy and commodious as could be desired. The hurricane deck affords a splendid promenade, and the midship portion of the vessel is devoted altogether to passengers. There are twelve staterooms on the upper deck and six below, besides a commodious saloon, ladies' room, smoking room, men's lavatory with a shower bath, etc. Aft of the saloon, which occupies the entire beam of the ship, like a modern ocean liner, is the pantry on the port side, connecting by a slide with the galley, and on the starboard side is the officers' mess. The captain's room is finished in polished oak, the pilot house and saloon and staterooms in cherry. The forecastle is forward and the stern is protected by a turtle back, under which is a lamp room, etc. The ship is supplied with all the modern improvements in the way of outfit, including Tyzack's triple grip stockless anchors, the Williamson steam steering gear and the American Ship Windlass Co.'s windlass.

The *Curacoa* sailed on her maiden voyage to Maracaibo on December 21, 1895.

Grand Duchess.—This passenger steamer, built for the Plant Investment Co., was launched by the Newport News Shipbuilding and Dry Dock Co. on January 30. The following description is compiled from the "Marine Journal," New York:

This vessel is built entirely of steel and has the following dimensions:

Length over all, 404 feet; length between perpendiculars, 380 feet; beam, 47 feet 9 inches; depth from top of deck to base line, 37 feet 4 inches. She will be fitted with two steel masts for fore-and-aft sails. The double bottom extends from the stuffing box bulkhead to the collision bulkhead. There are numerous watertight bulkheads and three continuous steel decks. The frames are of Z section.

The stern and rudder frames are of cast-steel, and the rudder stock of the best fluid compressed steel, manufactured by the Bethlehem Iron Works. The steering apparatus consists of Williamson Bros.' worm geared steam steering engines, operated

by an electrical telemotor. There are fitted a Providence steam windlass and capstan, Williamson Bros.' hoisting engines for handling cargo, and steam elevators in two of the hatches.

On the main deck forward is the dining saloon with a seating capacity for 125 people. This room is handsomely fitted up and decorated in white and gold. Forward of the dining room is a reception room and forward of this are sleeping accommodations for second class passengers. In the after end of the dining saloon is a grand stairway leading to the social hall above, the latter containing also a number of state rooms.

On the main deck aft of the dining saloon is a pantry, and aft of this, a large galley. On this deck are located cold storage for provisions, the officers' mess room, baker and porter shop, telephone exchange room, stewardess' room and a number of state rooms abreast of the boiler and engine hatches for oilers, water tenders, etc. Aft of the machinery is the main saloon with two tiers of state rooms on each side; in the forward end of this saloon is a grand stairway leading to the social hall above. Immediately aft of the main saloon are toilet, bath rooms, etc.

On the pilot house deck forward is the pilot house, aft of which are the captain's room and two tiers of state rooms continuing to the smoke pipe. Over the social hall aft is a large steel house fitted up as a ladies' observatory. All the social halls and main deck will be finished in mahogany as well as the ladies' observatory. The second-class social hall and reception room will be finished in quartered oak.

The vessel will be equipped with twelve life boats, six life rafts and the necessary life preservers, etc., and everything necessary for the safety of passengers and crew. There is a complete ventilating system connected to every compartment and stateroom in the vessel. The vessel will be fitted with a complete fire alarm system, a search light, and will be lighted by electricity, which will be furnished by two direct driven generators.

The machinery consists of twin-screw, inverted, direct acting, surface condensing, quadruple expansion engines, the total horse power being about 7,000. The propellers are of manganese bronze.

Steam will be supplied by eight Babcock & Wilcox water tube boilers, described and illustrated on page 702 of Vol. VII of the JOURNAL. There will be numerous Blake pumps for ballast, bilge, sanitary, fire and feed purposes, including the independent air pumps of the Blake Company's special vertical twin system, similar to those used on the large U. S. cruisers and battleships. The vessel has accommodations for about 300 first-class and 400 second-class, and has been designed in compliance with U. S. Government requirements for auxiliary cruisers.

The launch took place on Thursday morning between 9 and 9.30 o'clock, and the name of the steamer was not known until she started down the ways, when a large signboard bearing the selected name was lowered over the side of the vessel.

Comanche.—This steamer was built by the Wm. Cramp & Sons' S. and E. B. Co., Philadelphia, for the Clyde line. She was launched on August 2, 1895.

She is 300 feet long on the keel and 320 feet over all; the beam is 46 feet, and the depth of hold 26.3 feet; her gross tonnage is 3,202.44 tons.

The vessel carries over 250 passengers. The dining room, which extends across the vessel, and numerous staterooms abaft of the dining room, are below the upper deck. In the deck house above is the main saloon, surmounted by a glass dome, and reached from below by a grand stairway. The woodwork is all of antique oak and fittings luxurious. On the forward deck house is the pilot house. There are two light masts.

The single engine is of the quadruple expansion type, with cylinders 24½, 34½, 49½ and 70 inches in diameter and a stroke of 36 inches. The I.H.P., at full power, is about 3,000, the resulting speed being over 15 knots.

There are three single-ended cylindrical boilers, all 10 feet 7½ inches long. Two boilers are 15 feet 7½ inches in diameter, and the other one, 12 feet 9 inches in diameter. The steam pressure is 200 pounds per square inch.

North German Lloyd S. S. Co.—Contracts have been let by this Company for four twin-screw freight and passenger steamers for the New York line. The Vulcan Co. of Stettin will build

two; Messrs. Blohm & Voss of Hamburg one; and Mr. F. Schichau of Elbing one.

The general dimensions are

Length, feet	525
Beam, feet	64
Tonnage	10,000
Speed, knots	14

They will have accommodations for 200 cabin and from 1,500 to 2,000 steerage passengers.

Besides the above four, two other steamers are to be built, one by the Vulcan Works and one by Mr. Schichau, Elbing, of the following general dimensions: Length about 600 feet and beam about 66 feet. The price to be paid is about $4,750,000. The regular service speed will be about 21 knots. As each firm received the contract on its own plans, these vessels will not be sisters.

Rotterdam.—This steel steamer is building by Messrs. Harland & Wolff, Belfast, Ireland, for the Netherlands-American Steamship Co. The principal data being as follows:

Length, feet	470
Beam, feet	53
Depth, feet	40
I.H.P	12,500
Speed, knots	18

The registered tonnage will be about 8,000 tons. The engines will be triple expansion.

Queen City.—This lake steamer is building by the Cleveland Shipbuilding Co. for the Zenith Transit Co. Her length will be 400 feet. The Babcock & Wilcox boiler plant of this ship will be a duplicate of that of the Zenith City, described on page 765 of Vol. VII.

———.—A new steel package freight steamer building by the Union Dry Dock Co., Buffalo, N. Y. The new ship will be 335 feet long over all, have 44 feet beam and 27 feet 3 inches moulded depth, 50 inches of which will be taken up by water bottom. The engine is of the triple expansion type, with cylinders 23, 38½ and 64 inches in diameter by 42 inches stroke,

and is building by the King Iron Works, Buffalo. The four boilers, each 11½ feet in diameter and 13 feet long, are building by the Lake Erie Boiler works, also of Buffalo.

W. D. Rees.—This, the largest lake steamer now afloat, was launched on Monday, December 23, 1895, from the yard of the Cleveland Ship Building Co. for the Wilson Transit Co.

The principal dimensions are as follows:

Length over all, feet	415
on L.W.L.	395
Beam, feet	45
Depth, feet	28

The hull is built of steel on the channel system of construction. The double bottom is five feet deep and divided into eight compartments, each connected with pipe to a large ballast pump in the engine room. The steamer is for bulk cargo only, and has twelve hatches in the spar deck, spaced 24 feet from center to center. She will have the regular barge style of cabins forward and aft.

The engine is triple-expansion, with cylinders 23, 38 and 63 inches in diameter and a stroke of 40 inches. Steam will be supplied by two Scotch boilers, 14 feet in diameter, and 13 feet long, with a working pressure of 170 pounds per square inch.

The propeller is four-bladed and 13 feet in diameter.

There will be a steam windlass forward, a steam capstan aft, with two dock capstans on the spar deck and a Williamson steering engine forward.

Ignazio Floris.—This twin-screw steamer, intended for the between Naples and Palermo, Italy, and launched in November, 1895, was built by the Messrs. Orlando Bros., Leghorn. The following description is from the "Rivista Marittima," Rome:

The length between perpendiculars is 282.13 feet; beam, 34.94 feet; depth, 22.63 feet, and the displacement, 2,165 tons.

The double bottom extends for 200 feet of the length of the vessel. The boilers are protected by coal and by an inclined deck 1.57 inches thick, the vessel being built as an auxiliary cruiser.

The various saloons and staterooms are fitted up with great

luxury, there being room for 60 first and 50 second class passengers. The run between Naples and Palermo is to be made in 10 hours.

The engines are of the triple-expansion type and are designed for 4,000 I.H.P. The cylinders are 23.23, 37.4 and 59.1 inches in diameter and the stroke is 36.03 inches.

There are two double-ended, cylindrical boilers with four furnaces in each end, the working pressure being 155 pounds per square inch.

The expected speed is 17 knots.

YACHTS.

Josephine.—This steel yacht, designed by Lewis Nixon, is building by the Crescent Shipbuilding Co., for Mr. P. A. B. Widener, of Philadelphia. The general dimensions are as follows:

Length over all, feet	225
on L.W.L., feet	183
Beam, feet	28
Depth, feet	15
Draught, feet	11½
Displacement, tons	800
I.H P	1,250

The free board is 13 feet. There is a promenade deck, 18 feet wide and 135 feet long, on top of the deck house.

This house is of steel, 137 feet long, and is covered with mahogany. In the extreme forward part is the pilot house, chart room and captain's cabin, also a special stateroom for a distinguished guest. Aft of this are the galleys, a laundry, barber's shop, the engine room and then the dining room, which extends the whole width of the deck house. It will seat twenty-four persons and is to be finished in oak, mahogany and walnut. The extreme after end of the deck house, occupied by the owner's room, will be finished in mahogany and luxuriously fitted. Below these are to be ten large state rooms. Those occupied by the ladies will be most daintily furnished. The ladies' saloon, finished in white and gold, will have a handsome onyx mantel and electric logs, and there will be many inviting divans in nooks and corners.

The officers' ward room is located just forward of the boiler room.

The single-screw engine, with cylinders 18, 27 and 42 inches in diameter and a stroke of 28 inches, is building by Mr. J. W. Sullivan, of New York.

Steam will be supplied by two Scotch boilers, with a working pressure of 175 pounds per square inch.

Special provision has been made for the ventilation of the fire room and engine room and the coal bunker. The latter is a large compartment holding 210 tons of coal, and is located between the boiler and engine compartments. It occupies the entire width of the ship and has doors leading directly on the fire room floor.

The boat equipment will consist of a 30-foot steam launch, a 21-foot naphtha launch, a 20-foot whale boat, a 25-foot gig and a 16-foot dingy.

The electric light plant is to have a capacity of fifty 16 candle power incandescent lamps, which include a cable of lights that will be stretched over the masthead in port during ceremonies. There will also be a powerful Edison marine search light.

Steam steering gear will be fitted; hand gear is also provided. A refrigerating plant of the most modern type will be installed. There will be two masts for fore-and-aft sails. The estimated cost of the yacht complete is about $200,000.

————————.—This steel yacht is building for Mr. F. W. Morgan, of Chicago, by the Racine Boat Manufacturing Company, Racine, Wis. The hull was designed by Mr. Theodore Poekel and the machinery by the company. She is to conform to the requirements for auxiliary cruisers. There are 5 athwartship water tight bulkheads.

Length under water (ram), feet	140
Length on water line, feet	130
Beam, feet	18
Draught, feet	7½
Displacement, tons	140

Forward there will be a deck house containing the pilot house and dining room. The crew's quarters are to be forward and the state rooms aft. There will be 2 masts for fore-and-aft sails.

There is to be one 4-cylinder triple-expansion engine with cylinders 13, 15¾, and two of 20¼ inches in diameter, the stroke being 15 inches. With 300 revolutions per minute the I.H.P. will be 850 and the speed 15.5 knots; 60 I.H.P. are to be provided for in addition to the 850, for electric lighting, pumps, blowers and windlass.

The boiler will be of the Warrington water tube type with a working pressure of 230 pounds per square inch and grate surface of 53.5 square feet.

The propeller will be 5½ feet in diameter. The yacht complete will cost about $75,000.

Arcturus.—The trial of this yacht, described on page 856 of Vol. VII, was recently made. The steam pressure in boilers was 150 pounds per square inch, revolutions 140 per minute, and the mean speed nearly 11.75 knots over the measured mile. This speed was one knot more than was expected.

Iolaire.—This steam yacht, built by Messrs. Ramage and Ferguson, was launched at Leith for Sir Donald Currie, M. P., on Thursday, January 16. Her length is 203 feet; breadth, 27 feet 6 inches; depth, 17 feet 3 inches, and tonnage, about 700. The engine will be of the triple-expansion type, with cylinders 18 inches, 29½ inches and 48 inches in diameter, and a stroke of 33 inches. One large boiler will supply the steam up to 170 pounds working pressure. It is expected that 850 horse power will be developed, and a speed of from 12 to 13 knots realized. The figurehead of the vessel is a golden eagle (*Iolaire* being the Gaelic word for "Eagle.") She has two tall raking masts and one funnel. There is an extensive deck house, which, as well as the deck itself, is of teak; also a steering house on the navigating bridge. The cabins are fitted up in a particularly solid and artistic manner, the principal saloon in a specially selected Spanish mahogany.—(From "Engineering," London).

Margarita.—A steel steam yacht, to be built for Mr. A. J. Drexel, of Philadelphia. The designs are by Mr. Geo. L. Watson. The cost will be about $500,000.

Her length will be 290 feet. The designed speed is 16 knots. The twin-screw engines will be built by the Messrs. Rowan, Glasgow. The complement will be about 80 men.

Anita.—This steam yacht, built at Baltimore, Md., for Mr. A. Chanden, of New York, is 200 feet long over all.

The triple-expansion engine was built by Mr. J. W. Sullivan, New York, the cylinders being 16, 24 and 36 inches in diameter, with a stroke of 28 inches. With 230 revolutions per minute,

the expected horse power is 1,000 and the speed about 15½ knots. There are three Almy water tube boilers.

Hiawatha.—This composite steel yacht was designed and is building by Messrs. Charles L. Seabury & Co., of Nyack-on-Hudson, for Mr. Chas. Fleischman.

The following description is taken from the "Marine Record," Cleveland, Ohio:

The yacht is 135 feet long, has 16 feet 2 inches beam, 9 feet 6 inches depth and 7 feet draught. The hull is composite built. Frames and reverse frames are of angle steel, the keelsons, breast hooks and fore-and-aft plates of steel. The planking is of yellow pine and in two thicknesses. The fastenings are of Tobin bronze through bolts. There are four steel bulkheads. The rudder will be of bronze, with steel shank properly protected from the water. The deck will be of clear white pine fastened with lag screws from the under side of deck timbers.

There will be a mahogany deck house fitted on forward deck, the lower part paneled and the upper part fitted with heavy plate glass windows to slide up and down. Aft of the dining room and connecting with this saloon is a stateroom finished in mahogany. The bridge, with steering wheel, binnacle and a powerful search light, will be on top of the deck house. The chain locker will be fitted in the forehold. Directly aft of the chain locker and storeroom will be the crew's toilet room, aft of which will be fitted berths and lockers for the crew. The forecastle will also be used as a messroom for the crew, fitted with a folding table. Next aft are two staterooms, thoroughly ventilated by port lights, one for the captain and one for the engineer.

Aft of these staterooms is the galley, the full width of vessel, finished like the other rooms forward, in butternut, natural color. Aft of the galley will be the boiler and engine rooms; the bulkheads aft of boiler to be thoroughly protected from heat by non-conducting material. Directly aft of the boiler space will be the owner's stateroom, 6 feet 6 inches long, to extend the full width of the vessel, with the exception of a toilet room fitted on one side. This stateroom will be finely finished in mahogany. A skylight is arranged over this room for light and ventilation.

Aft of the owner's stateroom will be the main saloon, finished in mahogany, paneled on sides and ceiling, and properly ventilated by port lights and a skylight over the companion way. The entrance to saloon will be through a wide companion way leading direct from the deck.

Three guests' staterooms and an extra stateroom are aft of this saloon, and will be finished in butternut and mahogany. Aft of the saloon on port side will be a toilet room finished in butternut, and aft of this the lazarette. Steam heaters will be fitted in the owner's room, salon and dining hall on deck.

The machinery will consist of a Seabury triple-expansion engine of latest type, and a Seabury safety water tube boiler of improved design, with all fittings, etc., as required by law. The speed of the yacht is guaranteed at 16 miles per hour for three consecutive hours over a measured course. The vessel will be flush deck, schooner rigged. She will carry three boats besides a launch, and will be equipped with electric lights throughout.

Illawara.—This steam yacht is building at the Bath Iron Works for Mr. Eugene Tompkins, of Boston, Mass. The keel was laid during the latter part of December and the vessel will be completed next May. The designer of the yacht is Charles Ridgely Hanscom, of Bath, Me., designer of the steam yachts *Peregrine* and *Eleanor*. The principal dimensions are: length over all, 129 feet 10 inches; length on load water line, 106 feet 3 inches; beam, 18 feet 6 inches; depth of hold, 10 feet 6 inches; mean draught, 7 feet 6 inches. The vessel is very roomy for her class. The accommodation will comprise all the requisites necessary for comfort and convenience, the owner's quarters (consisting of four state rooms) and main saloon being on the lower deck aft. The officers and crew are berthed forward on the lower deck, and a deck house on the main deck forward is devoted to a galley, dining and observation rooms. The motive power is a vertical triple-expansion engine of 350 H.P., with cylinders 11, 19 and 30 inches in diameter by 18 inches stroke. The condenser is separate from the engine frame. The high pressure cylinder is placed in the center and the low pressure aft. The propeller is 4-bladed, of manganese bronze, 6 feet 6

inches diameter. There will be two Almy water tube boilers with a working pressure of 200 pounds. The coal bunkers have a capacity of about 20 tons of coal, and fresh water tanks are provided with a capacity of 2,500 gallons. The vessel is provided with a Williamson steam steerer and a Hyde steam brake windlass. She will have a complete electric plant, including a 12-inch search light and a storage battery of ten hours' endurance. She will carry 3 boats—a 20-foot naphtha launch, a 20-foot gig and a 14-foot dingy. She will have two pole masts, each about 52 feet high above deck, and will be rigged as a schooner with French sliding gaffs. The total sail area will be 2,500 square feet.—("American Shipbuilder," New York.)

Naphtha Yacht.—This twin-screw naphtha yacht, the largest of this type, is building by the Gas Engine and Power Company of Morris Heights, New York City, for Mr. Alfred Van Santvoord, owner of the side-wheel steam yacht *Clermont.*

The new yacht is to be used for cruising in the Florida rivers, and will be 76 feet long over all, have 12 feet 6 inches beam, and a draught of three feet. She will be built of cedar with oak frames and copper fastened, and have an overhanging bow and square stern.

The available space for the accommodation of the owner and his guests consists of a saloon and dining room forward, also two state rooms, one with single and one with double berths, all finished in white wood. There is extra provision for ventilation, and other arrangements to adapt the boat for these waters.

The fuel supply will be sufficient for a run of 500 miles at 9 knots. There will be a single mast, which will carry a try-sail, and which can be used as an auxiliary or when it is necessary to economize fuel. The crew comprises the captain, engineer and cook. Besides these there will be comfortable accommodations for six or eight guests.

The propelling machinery consists of two 12-H.P. naphtha motors, arranged to operate entirely independent of each other, so that in an emergency either or both may be used. They can be operated by one man.

BOOK REVIEW.

HOWELL'S STEAM VESSELS AND MARINE ENGINES.—This book will be of assistance, in spite of the absence of an index, to any one interested in the steam vessels of the United States and to engineers and shipbuilders who may want to compare the different types of engines now used. The collection in one book of the various types of marine engines used will often save much time and labor to the engineer who wishes to keep posted in regard to the designs and work of other engineers. It is interesting to compare the old *Savannah* with the modern trans-Atlantic steamer, and the latest designs of the best "liners" built in England with those of the United States.

The engravings and the description of the famous lake steamers *North West* and *North Land* must be of great interest to many of the engineers and shipbuilders on the sea coast. Few who have not been on the Great Lakes during the last two years realize the size of the steamers built there, or that two of the most modern steamships that fly the United States flag are on the lakes. The portion of the book devoted to steam yachts is valuable, as it gives a general idea of the different types in use. Their number is increasing so rapidly that their designing is becoming a specialty.

It is to be regretted that the space devoted to sailing vessels was not utilized by engravings of the different types of marine boilers now in use, more particularly the types of water tube boilers that have been adopted for marine service.

A description of the machinery of the large paddle wheel Sound steamers would have added to the value of the book, as they are so distinctively American in design.

OBITUARY.

PHILIP RANDALL VOORHEES.

The subject of this notice was for several years a member of the Engineer Corps, U. S. N , and after his resignation retained his interest in naval engineering matters in many ways, among them by becoming a member of the American Society of Naval Engineers.

Mr. Voorhees was born in Annapolis, Md., and could have boasted descent from patriotic revolutionary stock on both sides of his family. His father was Commodore Philip F. Voorhees, U. S. N., of New Jersey, who received a medal for gallant services in the war of 1812, under Decatur and Warrington in the capture of the *Macedonian* and *Epervier*.

Philip R. graduated at St. John's College, Annapolis, in 1855, as A. B., and afterwards became M. A. He studied mechanical engineering at a machine shop in Baltimore, entered the Navy as a Third Assistant Engineer, February 19, 1861, was promoted to Second Assistant Engineer, January 16, 1863, and became a First Assistant Engineer, December 1, 1864. During the civil war he served on the *Wabash* and *Huron*, and was present at the battles of Hatteras Inlet, Port Royal; in both bombardments of Fort Fisher and the engagements in the Cape Fear river, also in the James river; after the war he made a cruise on the *Tuscarora* in the South Seas. He resigned from the Navy, February 18, 1868, while attached to the Naval Academy as an instructor in steam engineering.

For awhile Mr. Voorhees was in the Examining Department of the U. S. Patent Office in Washington, D. C., but settled in New York as a counsellor-at-law, giving most attention to the patent branch of the profession. Besides being a member of the American Society of Naval Engineers he belonged to the Engi-

neers' Club of New York, the University and Lawyers' Clubs, the Military Order of the Loyal Legion, the New York Geographical Society, the New York Genealogical and Biographical Society (of which he was one of the officers), the American Society of Mechanical Engineers and the Society of Naval Architects and Marine Engineers.

Mr. Voorhees died in Lakewood, N. J., on December 12, 1895, and was buried in Annapolis. He was deservedly popular among his associates, to a privileged few of whom he always continued to be known as "Phil," and was a man of sterling worth, rare ability, and brilliant accomplishments.

ANNUAL MEETING.

The annual meeting of the Society was held on January 11 1896, in the office of the Engineer-in-Chief of the Navy.

Chief Engineer G. W. Baird, U. S. N., was elected chairman.

There being no papers for discussion before the Society, the report of the Secretary-Treasurer was read, showing a solid financial condition. The report is as follows:

WASHINGTON, D. C., *January* 11, 1896.

To the American Society of Naval Engineers.

Gentlemen: In accordance with the requirements of Section 14 of the By-Laws of the Society, I have the honor to submit the following report of the financial condition of the Society from December 22, 1894, to date:

RECEIPTS.

Balance on hand December 22, 1894	$1,633.35
Annual dues	2,285.16
Subscriptions, sales and reprints	954.35
Advertisements	995.30
Interest on deposit	59.72
	$5.927 88

EXPENDITURES.

Printing of JOURNAL	$2,034.13
Illustrations	295.49
Salary of Secreary-Treasurer	600.00
Stationery, postage and incidentals	112.91
Purchase of JOURNAL	69.50
Total	$3,112.03
Balance on hand January 11, 1896	$2,815.85

This balance is made up as follows:

On deposit with the American Security and Trust Company	$2,800.76
Cash on hand	15.09
Total	$2,815.85

Very respectfully,

R. S. GRIFFIN,
Secretary-Treasurer.

After the reading of the report, which was unanimously approved, the election of officers was held, with the following results:

President: Chief Engineer E. D. Robie, U. S. N., (retired.)

Secretary-Treasurer: Passed Assistant Engineer F. C. Bieg, U. S. N.

Members of Council, in addition to the President and Secretary-Treasurer:

Passed Assistant Engineer F. H. Bailey, U. S. N.; Passed Assistant Engineer B. C. Bryan, U. S. N.; Passed Assistant Engineer C. W. Dyson, U. S. N.

Passed Assistant Engineer R. S. Griffin, U. S. N., having declined a renomination as Secretary-Treasurer, a vote of thanks for his efficient and successful management of the affairs of the Society was given to him.

The following resolution was then introduced by P. A. Engineer F. C. Bieg, U. S. N., adopted by the meeting and ordered to be printed:

Resolved, That it is the sense of this meeting that the Council of the Society of American Naval Engineers should offer annually the sums of $75 and $25, and appropriate medals for the two best papers on any subjects suitable for the JOURNAL, and written by a member or associate member of this Society, subject to the following rules:

1. Papers must be original and submitted to the Secretary and Treasurer before the first of November of each year.

2. The Council of the Society shall judge the value of the papers submitted and award the prizes to the two best, and "honorable mention" to such other papers as deserve this.

3. Papers receiving the award of "honorable mention" shall be considered the property of the Society for publication in the JOURNAL.

4. All papers submitted shall bear a motto of the author, which motto shall be identified by a separate, sealed communication to the Secretary and Treasurer, giving the author's name and motto. These notes of identification shall be kept by the

Secretary and Treasurer, and opened only after the Council has given its judgment on the papers. Then the prizes and "honorable mention" shall be awarded by name and the papers published in the JOURNAL.

There being no further business, the meeting adjourned.

The report and accounts of the Secretary-Treasurer have since been audited and found to be correct.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

OFFICERS FOR 1896.

President:
Chief Engineer **Edward D. Robie**, U. S. Navy.

Secretary and Treasurer:
Passed Assistant Engineer **F. C. Bieg**, U. S. Navy.

Council:
Chief Engineer **Edward D. Robie**, U. S. Navy.
Passed Assistant Engineer **Frank H. Bailey**, U. S. Navy.
Passed Assistant Engineer **F. C. Bieg**, U. S. Navy.
Passed Assistant Engineer **B. C. Bryan**, U. S. Navy.
Passed Assistant Engineer **Charles W. Dyson**, U. S. Navy.

HONORARY MEMBERS.

(EX-OFFICIO.)

The Secretary of the Navy.

The Assistant Secretary of the Navy.

Chief of Bureau of Steam Engineering:
Geo. W. Melville, Engineer-in-Chief, U. S. N., Navy Department.

Ex-Chiefs of Bureau of Steam Engineering:
Chas. H. Haswell, Consulting and Superintending Engineer, 42 Broadway, New York.
B. F. Isherwood, Chief Engineer, U. S. N. (retired), 111 East 36th street, New York.
J. W. King, Chief Engineer, U. S. N. (retired), 3231 Powellton avenue, Philadelphia.
Chas. H. Loring, Chief Engineer, U. S. N. (retired), 239 Clermont avenue, Brooklyn.
Wm. H. Shock, Chief Engineer, U. S. N. (retired), 1404 15th street, Washington, D. C.

MEMBERS.

Able, A. H., Chief Engineer, U. S. N.....2034 Mt. Vernon street, Philadelphia, Pa.
Addicks, W. R., Engineer Bay State and Boston Gas Companies, 24 West street, Boston, Mass.
Aldrich, Wm. S., Professor Mechanical Engineering,
and Director Department of Mechanic Arts, West Virginia University, Morgantown, W. Va.
Allderdice, W. H., Passed Assistant Engineer, U. S. N.....U. S. S. *Bennington.*
Allen, D. Van H., Assistant Engineer U. S. N.....U. S. S. *Newark.*
Allen, F. B., Vice-President Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.
Anderson, M. A., Passed Assistant Engineer, U. S. N.....U. S. S. *New York.*
Andrade, Cipriano, Chief Engineer, U. S. N.....U. S. S. *New York.*
Aston, Ralph, Chief Engineer, U. S. N.....78 Hanson Place, Brooklyn, N. Y.
Ayres, S. L. P., Chief Engineer, U. S. N., Examining Board, P. O. Building, Philadelphia, Pa.

Bailey, F. H., Passed Assistant Engineer, U. S. N.,
Bureau Steam Engineering, Navy Department, Washington, D. C.
Baird, G. W., Chief Engineer, U. S. N.,
Superintendent State, War and Navy Dept. Bldg., Room 148, Navy Dept., Washington, D. C.
Baker, C. H., Chief Engineer, U. S. N. (retired).....1739 19th street, N. W., Washington, D. C.
Ball, Walter, Assistant Engineer, U. S. N.....U. S. S. *New York.*
Barnard, G. A., Mechanical Engineer.....115 Lincoln Ave., Salem, Ohio.

Barrett, Thos. H., late Assistant Engineer, U. S. N...Room 156, Postoffice Building, New York.
Barry, J. J., Passed Assistant Engineer, U. S. N. (retired),
106 McDonough street, Brooklyn, N. Y.
Bartlett, F. W., Passed Assistant Engineer, U. S. N..... ....Naval Academy, Annapolis, Md.
Barton, J. K., Chief Engineer, U. S. N.....U. S. S. *Bennington.*
Bates, A. B., Chief Engineer, U. S. N.....U. S. S. *Franklin.*
Baughman, H. C., Assistant Engineer, U. S. N. (retired), 2000 N. 12th street, Philadelphia, Pa.
Baxter, W. J., Naval Constructor, U. S. N.....Navy Yard, Mare Island, Cal.
Bayley, W. B., Chief Engineer, U. S. N.....U. S. S. *Monterey.*
Beach, E. L., Assistant Engineer, U. S. N..... .....U. S. S. *Ericsson.*
Bennett, F. M., Passed Assistant Engineer, U. S. N.....U. S. S. *Amphitrite.*
Bevington, Martin, Passed Assistant Engineer, U. S. N.....U. S. S. *Columbia.*
Bieg, F. C., Passed Assistant Engineer U. S. N.,
Bureau Steam Engineering, Navy Department, Washington, D. C.
Borthwick, J. L. D., Chief Engineer, U. S. N.....156 West 6th street, Erie, Pa.
Bowers, F. C., Passed Assistant Engineer, U. S. N.....U. S. S. *Maine.*
Boyd, Jas. T., Consulting Engineer.....28 State street, Boston, Mass.
Brady, John R., Assistant Engineer, U. S. N..... U. S. S. *Indiana.*
Bray, Chas. D., Professor Civil and Mechanical Engineering, Tufts College, College Hill, Mass.
Brecht, T. C......Bureau Steam Engineering, Navy Department, Washington, D. C.
Brooks, W. B., Chief Engineer, U. S. N. (retired).....437 West 6th street, Erie, Pa.
Bryan, B. C., Passed Assistant Engineer, U. S. N.,
Bureau of Steam Engineering, Navy Department, Washington, D. C.
Buehler, W. G., Chief Engineer, U. S. N.....Navy Yard, Portsmouth, N. H.
Burd, G. W., Passed Assistant Engineer, U. S. N.....U. S. S. *Cincinnati.*
Burgdorff, T. P., Passed Assistant Engineer, U. S. N.....U. S. S. *Thetis.*
Burke, W. S., Assistant Engineer, U. S. N.....27 Everett street, Cambridge, Mass.
Bush, W. W., Assistant Engineer, U. S. N.,
Inspector Machinery, Moran Bros'. Co., Seattle, Wash.

Canaga, A. B., Chief Engineer, U. S. N.,
Bureau Steam Engineering, Navy Department, Washington, D. C.
Capps, W. L., Naval Constructor, U. S. N.....Union Iron Works, San Francisco, Cal.
Carney, R. E., Assistant Engineer, U. S. N.....U. S. S. *Olympia.*
Carr, C. A., Passed Assistant Engineer, U. S. N.....U. S. S. *Marblehead.*
Carter, T. F., Passed Assistant Engineer, U. S. N.....U. S. S. *Lancaster.*
Cathcart, W. L., Mechanical Engineer.....Gwynedd, Pa.
Chambers, W. H., Passed Assistant Engineer, U. S. N.....Navy Yard, New York.
Cleaver, H. T., Passed Assistant Engineer, U. S. N.....U. S. S. *Alert.*
Cline, H. H., Chief Engineer, U. S. N. (retired).....634 Greene Ave., Brooklyn, N. Y.
Collins, Jno. W., Engineer-in-Chief Revenue Cutter Service,
Treasury Department, Washington, D. C.
Conant, F. H., Passed Assistant Engineer, U. S. N.....U. S. S. *Philadelphia.*
Cook, Allen M., Assistant Engineer, U. S. N.....U. S. S. *Amphitrite.*
Cooley, Mortimer E., Professor Mechanical Engineering,
University of Michigan, Ann Arbor, Mich.
Cooper, I. T., Naval Cadet, U. S. N.....U. S. S. *Raleigh.*
Cowie, George, Chief Engineer, U. S. N.....Experimental Board, Navy Yard, New York.
Cowles, Wm., Constructing Engineer and Naval Architect, 62 Fourth aveuue, Cleveland, Ohio.
Crawford, Robt., Passed Assistant Engineer, U. S. N., (retired),
Superintendent Williamson School, Williamson School Postoffice, Delaware Co., Pa.
Creighton, W. H. P., Assistant Engineer, U. S. N. (retired), 249 Camp street, New Orleans, La.
Cunningham, Thomas Scott, late First Assistant Engineer, U. S. N.,
196 La Salle street, Chicago, Ill.

Danforth, Geo. W., Assistant Engineer, U. S. N.....U. S. S. *New York.*
Day, W. B., Passed Assistant Engineer, U. S. N.....Navy Yard, New York.
Denig, R. G., Chief Engineer, U. S. N.....U. S. S. *Petrel.*

Dixon, A. F., Chief Engineer, U. S. N.....U. S. S. *Machias.*
Doran, James S., Superintending Engineer American Steamship Co.,
305 Walnut street, Philadelphia, Pa.
Dowst, F. B, General Superintendent B. F. Sturtevant Co.....Jamaica Plain, Boston, Mass.
Dripps, W. A., Mechanical Engineer.....3324 Walnut street, Philadelphia, Pa.
Dungan, W. W., Chief Engineer, U. S. N.,
Inspector Machinery, Cramp's Shipyard, Philadelphia, Pa.
Durand, W. F., Professor Marine Engineering and Naval Architecture,
Cornell University, Ithaca, N. Y.
Dunning, Wm. B, Passed Assistant Engineer, U. S. N.....U. S. S. *Olympia.*
Dyson, Charles W, Passed Assistant Engineer, U. S. N.,
U. S. Fish Commission, Washington, D. C.
Eaton, Wm. C., Chief Engineer, U. S. N.....U. S. S. *Vermont.*
Eckart, W. R, Mechanical Engineer.....217 Sansome street, San Francisco, Cal.
Edson, Jarvis B., Mechanical Engineer.....313 W. 74th street, New York.
Edwards, Jno. R., Chief Engineer, U. S. N.,
Bureau of Steam Engineering, Navy Department, Washington, D. C.
Eldridge, F. H, Passed Assistant Engineer, U. S. N.....Naval Academy, Annapolis, Md.
Emanuel, J. M., Passed Assistant Engineer, U. S. N. (retired), 1810 N. 12th st., Philadelphia, Pa.
Emery, Chas. E., Ph.D., Consulting Engineer.....916 Bennett Building, New York.
Engard, A. C., Chief Engineer, U. S. N.....2131 North 19th street, Philadelphia, Pa.

Farmer, Edward, Chief Engineer, U. S. N.....Navy Yard, New York.
Ferguson, Geo. R., Mechanical Engineer, 179 Washington street, Brooklyn, N. Y.;
Residence, 26 South Grove street, East Orange, N. J.
Fisher, Clark, Civil and Mechanical Engineer.....Eagle Anvil Works, Trenton, N. J.
Fitch, H. W., Chief Engineer, U. S. N., (retired)...1518 Connecticut avenue, Washington, D. C.
Ford, Jno. D., Chief Engineer, U. S. N.....Maryland Mechanical and Agricultural College.
Freeman, E. R., Passed Assistant Engineer, U. S. N.,
Steel Inspection Board, Navy Yard, Washington, D. C.

Gage, Howard, Passed Assistant Engineer, U. S. N., Care Navy Department, Washington, D. C.
Galt, Robert W., Chief Engineer, U. S. N.....U. S. S. *Yantic.*
Gow, J. L., Passed Assistant Engineer, U. S. N.....U. S. S. *Raleigh.*
Greene, A. S., Chief Engineer, U. S. N. (retired).....The Cairo, Washington, D. C.
Greene, Levi R., late First Assistant Engineer, U. S. N.....71 Walnut street, Natick, Mass.
Greene, D. M., Consulting Engineer.....41 First street, Troy, N. Y.
Griffin, R. S., Passed Assistant Engineer, U. S. N.,
Bureau Steam Engineering, Navy Department, Washington, D. C.
Gsantner, O. C., First Assistant Examiner, U. S. Patent Office;
Residence, 1708 New Jersey avenue, Washington, D. C.

Habighurst, C. J., Chief Engineer, U. S. N.....U. S. S. *Terror.*
Hall, H., Passed Assistant Engineer, U. S. N.....U. S. S. *Indiana.*
Hall, R. T., Passed Assistant Engineer, U. S. N.....Navy Yard, New York.
Halstead, A. S., Passed Assistant Engineer, U. S. N.,
Inspector Machinery, J. H. Dialogue & Son, Camden, N. J.
Hannum, J. L., Chief Engineer, U. S. N.....U. S. S. *Amphitrite.*
Harris, Wm. H., Chief Engineer, U. S. N.....U. S. S. *Columbia.*
Hartrath, Armin, Assistant Engineer, U. S. N.....Care Navy Department, Washington, D. C.
Hasbrouck, R. D., Assistant Engineer, U. S. N.....Care Embassy of the United States, Paris.
Hasson, W. F. C., Consulting Mechanical and Electrical Engineer,
310 Pine street, San Francisco, Cal.
Hayes, Charles H., Passed Assistant Engineer, U. S. N.....Cramp's Shipyard, Philadelphia.
Henderson, Alexander, Chief Engineer, U. S. N. (retired),
Treasurer Manhattan Rubber Manufacturing Co., 64 Cortlandt street, New York.
Herbert, W. C., Passed Assistant Engineer, U. S. N.....55 Saunders ave., West Philadelphia.
Herwig, H., Chief Engineer, U. S. N. (retired).....Alexandria, Va.

Hibbs, F. W., Assistant Naval Constructor, U. S. N.....Navy Yard, New York.
Hichborn, Philip, Chief Constructor, U. S. N.....Navy Department.
Higgins, R. B., Passed Assistant Engineer, U. S. N.....Navy Yard, Norfolk, Va.
Hogan, Thomas J., Mechanical Engineer.....Box 950, Pittsburgh, Pa.
Hollis, Ira N., Professor of Engineering, Harvard University.....Cambridge, Mass.
Holmes, U. T., Assistant Engineer, U. S. N.....U. S. S. *Charleston.*
Howell, C. P., Chief Engineer, U. S. N.....U. S. S. *Maine.*
Hunt, A. M., Consulting Engineer.....310 Pine street, San Francisco, Cal.

Inch, Richard, Chief Engineer, U. S. N.....Navy Yard, Mare Island, Cal.
Inch, Philip, Chief Engineer, U. S. N.....Navy Yard, Washington, D. C.

Johnson, George R., Chief Engineer, U. S. N., (retired),
1233 New Hampshire avenue, Washington, D. C.
Jones, David P., Chief Engineer, U. S. N. (retired).....333 Rookery Building, Chicago, Ill.
Jones, Horace W., Assistant Engineer, U. S. N.....Naval Academy, Annapolis, Md.
Jones, Owen.....68 Great Russell street, London, W. C., England.

Kaemmerling, Gustav, Passed Assistant Engineer, U. S. N.,
Bureau Steam Engineering, Navy Department.
Kafer, John C., Passed Assistant Engineer, U. S. N. (retired),
Secretary and Superintendent of the Morgan Iron Works, New York City.
Kearney, George H., Chief Engineer, U. S. N.....U. S. S. *Marblehead.*
Keilholtz, Pierre O., Electrical and Mechanical Engineer, 330 N. Charles street, Baltimore, Md.
King, C. A. E., Passed Assistant Engineer, U. S. N.....U. S. S. *Newark.*
King, W. R., Passed Assistant Engineer, U. S. N. (retired),
Commandant of Cadets Cheltenham Military Academy, Ogontz, Pa.
Kinkaid, T. W., Passed Assistant Engineer, U. S. N.....U. S. S. *Terror.*
Kirby, Absalom, Chief Engineer, U. S. N.....U. S. S. *Monadnock.*
Koester, O. W., Assistant Engineer, U. S. N .....U. S. S. *Cushing.*
Kutz, George P., Chief Engineer, U. S. N.....Navy Yard, Mare Island, Cal.

Laws, E., Chief Engineer, U. S. N. (retired).....145 Washington street, Morristown, N. J.
Laws, G. W., Assistant Engineer U. S. N.....U. S. S. *Raleigh.*
Leavitt, E. D., Mechanical Engineer.....2 Central Square, Cambridgeport, Mass.
Leitch, R R., Chief Engineer, U. S. N.....51 South Oxford street, Brooklyn N. Y.
Leonard, J. C., Passed Assistant Engineer, U. S. N.....U. S. S. *Charleston.*
Leonard, S. H., Passed Assistant Engineer, U. S. N.....U. S. S. *Charleston.*
Leopold, H. G., Passed Assistant Engineer, U. S. N.. .....U. S. S. *Monterey.*
Linnard, Joseph H., Naval Constructor, U. S. N.....Cramp's Ship Yard, Philadelphia, Pa.
Little, W. N., Passed Assistant Engineer, U. S. N., Care Navy Department, Washington, D. C.
Loyd, John.....558–562 Water street, New York.
Lowe, John, Chief Engineer, U. S. N.....U. S. S. *Philadelphia.*

McAllister, Andrew, Passed Assistant Engineer, U. S. N .....U. S. S. *Indiana.*
McAlpine, Kenneth, Passed Assistant Engineer, U. S. N.,
Newport News S. B. and D. D Co , Newport News, Va.
McCartney, D. P., Chief Engineer, U. S. N. (retired), 1704 19th St., N. W., Washington, D. C.
McCutchen, J. F., late Chief Engineer, U. S. N.....2206 N. 15th street, Philadelphia, Pa.
McElmell, Jackson, Chief Engineer, U. S. N.,
President Board of Examiners, P. O. Building, Philadelphia, Pa.
McElmell, Thomas A., late Second Assistant Engineer, U. S. N.,
1931 Spring Garden street, Philadelphia, Pa.
McElroy, G. W., Passed Assistant Engineer, U. S. N.....U. S. S. *Adams.*
McFarland, W M., Passed Assistant Engineer, U. S. N.....U. S. S. *San Francisco.*
McKean, Fred G, Chief Engineer, U. S. N. (retired)..1323 11th street N. W., Washington, D. C.
McKean, J. S., Passed Assistant Engineer, U. S. N.....U. S. S. *Minneapolis.*
McNary, I. R., Chief Engineer, U. S. N. (retired).....

Maccarty, G. M. L., Chief Engineer, U. S. N.....U. S. S. *San Francisco.*
Macomb, D. B., Chief Engineer, U. S. N. (retired), 28 Arlington street, North Cambridge, Mass.
Magee, E. A., Chief Engineer, U. S. N. (retired).....187 Marcy avenue, Brooklyn, N. Y.
Magee, Geo. W., Chief Engineer, U. S. N. (retired).....187 Marcy avenue, Brooklyn, N. Y.
Main, Herschel, Chief Engineer, U. S. N. (retired), 2009 Mass. Ave., N. W., Washington, D. C.
Manning, Chas. H., Passed Assistant Engineer, U. S. N. (retired),
General Superintendent Amoskeag Manufacturing Co., Manchester, N. H.
Mathews, C. H., Passed Assistant Engineer, U. S. N.....U. S. S. *Detroit.*
Mattice, A. M., Mechanical Engineer.....2 Central Square, Cambridgeport, Mass.
Merritt, D. R., Naval Cadet, U. S. N.....U. S. S. *Indiana.*
Mickley, J. P., Chief Engineer, U. S. N.....Mickley's, Lehigh Co., Pa.
Milligan, R. W., Chief Engineer, U. S. N.....Annapolis, Md.
Moody, Roscoe C., Naval Cadet, U. S. N.....U. S. S. *New York.*
Moore, Jno. W., Chief Engineer, U. S. N. (retired).....98 S. Oxford street, Brooklyn, N. Y.
Moore, Wm. S., Chief Engineer, U. S. N.....U. S. S. *Dolphin.*
Morgan, Leo, Mechanical Engineer.....519 19th street, San Francisco, Cal.
Moritz, Albert, Passed Assistant Engineer, U. S. N.....U. S. S. *Monterey.*
Morley, A. W., Chief Engineer, U. S. N.....260½ Kosciusko street, Brooklyn, N. Y.

Nauman, Wm. H., Chief Engineer, U. S. N.....U. S. S. *Alliance.*
Nones, Henry B., Chief Engineer, U. S. N. (retired).....1107 Franklin street, Wilmington, Del.
Norton, H. P., Passed Assistant Engineer, U. S. N.....Bureau Steam Engineering, Navy Dept.
Nulton, Louis M., Assistant Engineer, U. S. N.....Naval Academy, Annapolis, Md.

Ogden, J. S., Chief Engineer, U. S. N.....U. S. S. *Montgomery.*
Offley C. N., Assistant Engineer, U. S. N.....Columbian I. W. and D. D. Co., Baltimore, Md.

Parks, W. M., Passed Assistant Engineer. U. S. N.,
Inspector Machinery, Columbian I. W. and D. D. Co., Baltimore, Md.
Patton, J. B., Assistant Engineer, U. S. N.....U. S. S. *Concord.*
Pemberton, John, Passed Assistant Engineer, U. S. N. (retired).,
24 Hawthorne avenue, E. Orange, N. J.
Perry, J. H., Chief Engineer, U. S. N.....Bureau of Steam Engineering, Navy Department.
Peugnet, M. B., late Assistant Engineer, U. S. N., Care E. Peugnet, 89 Water street, New York.
Pollock, E R., Assistant Engineer, U. S. N.....Care Navy Department, Washington, D. C.
Porter, John S., Assistant Engineer, U. S. N.....Care Embassy of the United States, Paris.
Potts, Stacy, Chief Engineer, U. S. N.....U. S. S. *Essex.*
Pickrell, J. M., Passed Assistant Engineer, U. S. N.....U. S. S. *Marion.*
Powers, W. A., Superintendent Steam Boiler Inspection.....Brooklyn, N. Y.
Price, C. B., Assistant Engineer, U. S. N.....U. S. S. *San Francisco.*
Price, H. B., Assistant Engineer, U. S. N.....U. S. S. *Philadelphia.*
Procter, A. M., Assistant Engineer, U. S. N.....U. S. S. *Maine.*

Rae, Charles Whiteside, Chief Engineer, U. S. N.....Naval Academy, Annapolis, Md.
Ransom, G. B., Chief Engineer, U. S. N.,
Inspector Machinery, Crescent S. B. Co., Elizabethport, N. J.
Read, Frank D., Assistant Engineer, U. S. N.....U. S. S. *Monadnock.*
Rearick, P. A., Chief Engineer, U. S. N.....U. S. S. *Indiana.*
Redgrave, DeWitt C., Passed Assistant Engineer, U. S. N.....U. S. S. *Montgomery.*
Reed, Milton E., Assistant Engineer, U. S. N.....U. S. S. *San Francisco.*
Reeves, I. S. K., Passed Assistant Engineer, U. S. N.....U. S. S. *Katahdin.*
Reeves, Jos. M., Naval Cadet, U. S. N.....U. S. S. *San Francisco.*
Reid, R. I., Passed Assistant Engineer, U. S. N.....U. S. S. *Michigan*, Erie, Pa.
Rhoades, Henry E., Engineer Corps, U. S. N. (retired),
141 South 2d avenue, Mount Vernon, New York.
Roberts, Edward E., President The Roberts Safety Water Tube Boiler Co.,
39 and 41 Cortlandt street, New York.
Robie, Edward D., Chief Engineer, U. S. N. (retired), 1331 21st St., N. W., Washington, D. C.

Robison, John K., Assistant Engineer, U. S. N.....U. S. S. *Olympia*.
Robinson, L. W., Chief Engineer, U. S. N.....U. S. S. *Newark*.
Roche, G. W., Chief Engineer, U. S. N.....1304 McCulloh street, Baltimore, Md.
Roelker, C. R., Chief Engineer, U. S. N.....U. S. S. *Raleigh*.
Rommell, C. E., Passed Assistant Engineer, U. S. N.....Navy Yard, New York.
Ross, Henry Schuyler, Chief Engineer, U. S. N., Experimental Board, Navy Yard, New York.

Salisbury, G. R., Passed Assistant Engineer, U. S. N.....U. S. S. *Fern*.
Sampson, B. C., Passed Assistant Engineer, U. S. N.....U. S. S. *Philadelphia*.
Schell, F. J., Passed Assistant Engineer, U. S. N.....U. S. S *New York*.
Scribner, E. H., Passed Assistant Engineer, U. S. N.....U. S. S. *Boston*.
Selden, W. C., Superintending Engineer Clyde Line Steamers.....Pier 29 East River, New York.
Shepard, George H., Assistant Engineer, U. S. N.....U. S. S. *Columbia*.
Sloane, John D., Assistant Engineer U. S. N. (retired).....447 Marshall avenue, St. Paul, Minn.
Smith, David, Chief Engineer, U. S. N.....1714 Conn. avenue, Washington, D. C.
Smith, J. A. B., Chief Engineer, U. S. N.....U. S. S. *Texas*.
Smith, S. L., Superintendent Roxbury Carpet Co.....37 Simmons street, Boston, Mass.
Smith, W. S., Chief Engineer, U. S. N.....Examining Board, P. O. Building, Philadelphia, Pa.
Smith, W. Strother, Passed Assistant Engineer, U. S. N.....U. S. S. *Newark*.
Smith, W. Stuart, Assistant Engineer, U. S .N. (retired).....2538 Dwight Way, Berkeley, Cal.
Snow, Elliot, Assistant Naval Constructor, U. S. N.....Navy Yard, Mare Island, Cal.
Spangler, Henry W., Prof. Mechanical Engineering, University of Pennsylvania, Philadelphia.
Stevenson, H. N., Chief Engineer, U. S. N., Inspector Machinery, Bath Iron Works, Bath, Me.
Stickney, Herman O., Assistant Engineer, U. S. N.....Naval Academy, Annapolis, Md.
Strickland, Geo. D., Passed Assistant Engineer, U. S. N. (retired), No. 1 State St., Media, Pa.

Tawresey, John G., Assistant Naval Constructor, U. S. N.....Cramp's Ship Yard, Philadelphia.
Taylor, D. W., Naval Constructor, U. S. N.,
Bureau Construction and Repair, Navy Department.
Taylor, R. D., Passed Assistant Engineer, U. S. N. (retired), 3212 Haverford Ave., Philadelphia.
Theiss, Emil, Passed Assistant Engineer, U. S. N.....U. S. S. *Albatross*.
Thomson, James W., Chief Engineer, U. S. N.,
Inspector Machinery, Newport News S. B. and D. D. Co., Newport News, Va.
Tobin, J. A., Engineer Corps, U. S. N. (retired).....19 Cliff street, New York City.
Tower, George E., Chief Engineer, U. S. N.....Navy Yard, New York.
Towne, N. P......Care Cramp & Sons, Philadelphia.
Trench, M. E., Assistant Engineer, U. S. N.....U. S. S. *Maine*.
Trilley, Joseph, Chief Engineer, U. S. N.....Care Navy Department, Washington, D. C.

Van Buren, J. D., Civil Engineer.....Newburg, N. Y.
Varney, W. H., Naval Constructor, U. S. N.....1001 Harlem avenue, Baltimore, Md.

Warburton, Edgar T., Passed Assistant Engineer, U. S. N., 4412 Chestnut St., Philadelphia, Pa.
Warren, B. H., Assistant Engineer U. S. N. (retired),
The Electro Magnetic Traction Co., 120 Broadway, New York City.
Weaver, W. D., Electrical Engineer.....7 West 26th street, New York City.
Webster, H., Chief Engineer, U. S. N.....U. S. S. *Yorktown*.
Wharton, B. B. H., Chief Engineer, U. S. N. (retired).....69 Christopher street, Montclair, N. J.
White, W. W., Passed Assistant Engineer, U. S. N.....U. S. S. *Minneapolis*.
Whitham, Jay M......131 S. 3d street, Philadelphia.
Williamson, John D. (late Chief Engineer, U. S. N.),
Williamson Bros., Engineers, York and Richmond streets, Philadelphia.
Willits, A. B., Passed Assistant Engineer, U. S. N.....U. S. S. *Minneapolis*.
Willits, Geo. S., Passed Assistant Engineer, U. S. N.....American Steel Casting Co., Thurlow, Pa.
Wilson, F. A., Chief Engineer, U. S. N.....Union Iron Works, San Francisco, Cal.
Windsor, W. A., Chief Engineer, U. S. N.....U. S. S. *Minneapolis*.
Winchell, Ward P., Passed Assistant Engineer, U. S. N.....U. S. S. *Enterprise*, Boston, Mass.

Wood, B. F., Chief Engineer, U. S. N. (retired).....213 N. Fulton avenue, Mount Vernon, N. Y.
Wood, Jos. L., Assistant Engineer U. S. N. (retired),
Webb's Academy and Home for Shipbuilders, Fordham Heights, New York City.
Woodward, J. J., Naval Constructor, U. S. N.,
Newport News S. B. & D. D. Co., Newport News, Va.
Worthington, W. F., Passed Assistant Engineer, U. S. N.....U. S. S. *Castine*.

Zane, A. V., Chief Engineer, U. S. N.....U. S. S. *Monocacy*.
Zeller, Theo., Chief Engineer, U. S. N., with relative rank of Commodore (retired),
15 West 12th street, New York.

ASSOCIATES.

Aborn, George Pennell, Assistant Engineer of Construction,
Knowles' Steam Pump Works, Warren, Mass.
Almy, Darwin, President and Treasurer Almy Water Tube Boiler Co.,
178 to 184 Allen avenue, Providence, R. I.
Angstrom, Arendt, General Manager The Bertram Engine Works Co.....Toronto, Canada.
Archambault, C. V......234 East Montgomery street, Baltimore, Md.

Babcock, W. I., Manager Chicago Shipbuilding Co.....South Chicago, Ill.
Bailey, Charles F., Chief Draughtsman, Engineering Department,
Newport News Shipbuilding and Dry Dock Co., Newport News, Va.
Bailey, W. H., Agent American Tube Works.....20 Gold street, New York.
Baker, F. W., Columbian Iron Works.....Baltimere, Md.
Barrows, H. C., Chief Engineer, U. S. R. C. S.....Steamer *Grant*, Port Townsend, Wash.
Bartlett, George B., Superintendent of Construction, Illinois Steel Co.....South Chicago, Ill.
Beavor-Webb, J., Naval Architect and Engineer.....45 Broadway, New York.
Belcher, A. W., Superintendent Repair Shops, Cornell Steamboat Co.....Rondout, N. Y.
Biles, J. Harvard, Professor Naval Architecture, University of Glasgow.....Glasgow, Scotland.
Binney, Arthur.....181 Tremont street, Boston, Mass.
Bissell, G. W., Professor of Mechanical Engineering, Iowa Agricultural College.....Ames, Iowa.
Blake, D. W., Second Assistant Engineer, U. S R. C. S.....Steamer *Galveston*, Galveston, Tex.
Blauvelt, Albert, Electrician.....626 Rialto Building, Chicago, Ill.
Bloedel, J. H., Secretary Blue Canyon Coal Mining Co.....New Whatcom, Wash.
Blomberg, C. A., Marine Engineer, Wm. Cramp & Sons' S. & E. B. Co.....Philadelphia.
Bolten, A., Owner Zeise's Patent Propeller for United States,
850 Market street, San Franciso, Cal.
Bonneville, A. A. de, Mechanical Engineer.....95 Liberty street, New York.
Broadbent, A. L., Chief Engineer, U. S. R. C. S.,
Inspector Machinery, Moran Bros.' Co., Seattle, Wash.

Calder, C. B., Superintendent Dry Dock Engine Works.....Detroit, Mich.
Carnes, W. F., Mechanical Engineer, Care The Harlan and Hollingsworth Co., Wilmington, Del.
Christopher, J. Carstairs.....1826 Bolton street, Baltimore, Md.
Coleman, Edward P., Chief Draughtsman, Huber Printing Press Co.....Taunton, Mass.
Cook, John T., Chief Engineer S. S. *Cape Ann*, B. & G. S. B. Co., Central Wharf, Boston, Mass.
Coryell, Miers, Consulting Engineer.....117 Queen Victoria street, London.
Cox, Irving, Naval Architect.....1 Broadway, New York.
Cramp, Benjamin H., Brass Founder.....York and Thompson streets, Philadelphia.
Cramp, Courtland D., Brass Founder.....York and Thompson streets, Philadelphia.
Cramp, Edwin S., Superintending Engineer, Wm. Cramp & Sons' S. & E. B. Co., Philadelphia.
Cramp, Walter S., Cramp & Sons.....Philadelphia.
Currier, John A......P. O. Box 472, West Newton, Mass.
Curtis, Ralph E......Care Babcock & Wilcox Co., 29 Cortlandt street, New York.
Cust, Leopold, Engineer.....99 Onslow Square, London, S. W., England.

Dallett, W. P., Sales Agent for the Deane Steam Pump Co.....49 North 7th street, Philadelphia.
Davidson, Marshall T., Mechanical and Hydraulic Engineer,
43 to 53 Keap street, Brooklyn, N. Y.
Davis, Leonard D., Davis-Farrar Co., Builders of Marine Engines, Boilers and Steam Yachts,
Erie, Pa.
DeKinder, J. J., Consulting Engineer and Attorney at Law.....Girard Building, Philadelphia, Pa.
DeRycke, Joseph, Steam Specialties.....39 and 41 Cortlandt street, Taylor Building, New York.
Dickinson, Randall T., Superintending Constructor,
Delaware River Iron Shipbuilding and Engine Works, Chester, Pa.
Dorry, J. E., First Assistant Engineer, U. S. R. C. S.....Steamer *Bear*, San Francisco, Cal.
Dow, George E., Proprietor Dow Steam Pump Works, 114-116 Beale street, San Francisco, Cal.
Dowd, Thos. F., Superintendent Ewart Mfg. Building.....Chicago, Ill.
DuBosque, F. L., Assistant Engineer, Floating Equipment, Pennsylvania Railroad Co.,
Jersey City, N. J.
Dunell, George R., Marine Engineer,...9 Grove Park Terrace, Chiswick, W., London, England.

Elgar, Francis, LL. D., Naval Architect.....113 Cannon street, London, E. C., England.
Elliott, W. E., Superintending Engineer Goodrich Transportation Co.....Chicago, Ill.
Everest, Charles M., Vice President Vacuum Oil Company.....Rochester, N. Y.

Fehrenbatch, John.....Cincinnati, Ohio.
Ferguson, Wilfred H., Fairfield Works.....Govan, Glasgow, Scotland.
Field, C. J., Consulting Engineer.....Havemeyer Building, New York.
Fletcher, Andrew, Jr., Draughtsman and Director, W. & A. Fletcher Co.,
Hudson, 12th to 14th street, Hoboken, N. J.
Fletcher, Wm. H., of firm of W. & A. Fletcher Co., Hudson, 12th to 14th street, Hoboken, N. J.
Foran, George J., with The Geo. F. Blake Manufacturing Co.;
residence, 356 Harvard street, Cambridge, Mass.
Forsyth, Robert, Chief Engineer of the Union Iron Works.....San Francisco, Cal.
Frear, Hugo P., Naval Architect.....Union Iron Works, San Francisco, Cal.
French, D. McC., Chief Engineer, U. S. R. C. S.....Steamer *Rush*, San Francisco, Cal.
Frerichs, J. A., Marine Engineer, with Easton & Anderson.....Erith, Kent, England.
Fry, Alfred Brooks, Chief Engineer U. S. Treasury Service (Lieut. and Engineer
Massachusetts Naval Brigade), P. O. Building, Boston, Mass.

Gray, Evan M., Draughtsman with Donald Currie & Co.,
Orchard House, Blackwall, London, Eng.
Green, C. M., First Assistant Engineer, U. S. R. C. S.,
Revenue Marine Division, Treasury Department, Washington, D. C.
Greene, Isaac C......27 Westminster street, Providence, R. I.
Griffith, Edwin (Whitworth Scholar), Leading Draughtsman, Fairfield Engine Works, Govan;
Residence, 6 Ardgowan Ter., Glasgow, W., Scotland.
Gundersen, A., Chief Draughtsman for the John N. Robins Co.,
Erie Basin Dry Docks, Brooklyn, N. Y.

Hall, Bicknell, Mechanical Engineer.....Taunton, Mass.
Hanscom, I. C., Naval Architect.....62 Washington avenue, Chelsea, Mass.
Harris, Jas. H., Manager Heine Safety Boiler Co.....1521 Monadnock Building, Chicago, Ills.
Heffernan, J. T., President Puget Sound Engineering Works.....Port Townsend, Wash.
Henderson, A. P......446 Clinton street, Brooklyn, N. Y.
Hedden, Edward F., Chief Engineer, U. S R. C. S. (retired).
Henning, Gus C., Consulting Engineer, 762 Temple Court, No. 5 Beekman St., New York City.
Henthorn, John T., Remington & Henthorn, Engineers.....Providence, R. I.
Hoffmire, John D., Ship and Steamboat Joiner.....808 5th street, New York.
Hollingsworth, Sumner, President Hollingsworth & Whiting Co.;
residence, 44 Federal street, Boston, Mass.
Howell, William Neill, Mechanical Engineer, Wm. Cramp & Sons' S. & E. B. Co.,
Philadelphia.

Hoxie, Wm. D., In charge Marine Boiler Department, Babcock & Wilcox Co., 29 Cortlandt steeet, New York.
Hunsiker, Millard, Assistant to Chairman, Carnegie Steel Co., Limited .....Pittsburgh, Pa.
Hyde, Charles E., Marine Engineer, Bath Iron Works.....Bath, Me.
Hyde, John Sedgwick, Superintendent Engineering Department, Bath Iron Works.....Bath, Me.

Janson, Ernest N., Mechanical Engineer...802 Rhode Island avenue, N. W., Washington, D. C.
Jefferis, J. E., Chief Engineer, U. S. R. C. S.....Globe Iron Works, Cleveland, Ohio.
Jordan, S. S., Assistant Superintendent, Newport News S. B. and D. D. Co., Newport News, Va.

Katzenstein, L., Manufacturer of Metallic Packing and General Machinists' and Engineers' Supplies.....357 West street, New York.
Kelley, D. F., Chief Engineer, U. S. R. C. S.....2223 Howard street, Philadelphia, Pa.
Keough, William T., Engineer.....The Atlantic Works, East Boston, Mass.
Kerlin, J. M. Sharpless, Mechanical Engineer, Cowles Engineering Co., foot 44th street, Brooklyn, N. Y.
Kersey, H. Maitland, Agent White Star Line.....29 Broadway, New York City.
Kimball, G. H......95 Adelbert avenue, Cleveland, Ohio.
King, Frank B., Marine Engineer.....1019 St. Paul street, Baltimore, Md.
Kirby, Frank E., Marine Engineer.....Detroit, Mich.

Laval, George de, Superintendent and Constructing Engineer, Knowles' Steam Pump Works, Warren, Mass.
Lincoln, J. M., Assistant Superintending Engineer, Clyde Steamship Co. (Pier 29, East River), residence, 405 Lenox avenue, New York.
Livingstone W. A., Marine Engineer.....12 Woodward avenue, Detroit, Mich.
Loring, Harrison, Jr., Mechanical Engineer.....33½ India street, South Boston, Mass.
Lovell, Ralph L......P. O. Box 528, Newport News, Va.
Lundborg, C. G., Naval Architect.....233 West 135th street, New York.

Macalpine, John H......3303 Sixteenth street, N. W., Washington, D. C.
Maccoun, W. E., First Assistant Engineer, U. S. R. C. S...Steamer *Grant*, Port Townsend, Wash.
McAllaster, Eugene L., Mechanical Engineer and Naval Architect, 503-504 Pioneer Building, Seattle, Wash.
McAllister, Charles A., First Assistant Engineer, U. S. R. C. S., Revenue Marine Division, Treasury Department, Washington, D. C.
McDermott, Geo. R., Professor of Naval Architecture.....Cornell University, Ithaca, N. Y.
McMakin, Joseph, Superintending Engineer, U. S. Light House Board, 1601 McCulloh street, Baltimore, Md.
Magoun, Francis P......15 Wall street, New York.
Maschmeyer, A. M. P......Bureau Steam Engineering, Navy Department.
Mason, Thos., Chief Engineer, Marshall Field Building, 761 West Congress street, Chicago, Ill.
Matsuda, S., Imperial Japanese Navy.....Naval Department, Tokio, Japan.
Maxwell, W. L., Assistant Engineer, U. S. R. C. S.....Steamer *Rush*, San Francisco, Cal.
Mellin, Carl J., Chief Draughtsman Richmond Locomotive and Machine Works, Residence, 806 E. Leigh street, Richmond, Va.
Merritt, Jas. H., Marine Engineer.....70 Winter street, Portland, Me.
Miller, Walter, Mechanical Engineer.....338 Amesbury avenue, Cleveland, Ohio.
Mills, Abner B., Coppersmith.....127 Avenue D, New York.
Montgomery, H. M., Goubert Manufacturing Co.....16 Church street, New York.
Mooney, Thomas, Engineer.....Morgan Iron Works, 9th street and East River, New York.
Morris, Edward T......Union Iron Works, San Francisco, Cal.
Mosher, Charles D., Naval Architect and Marine Engineer.....1 Broadway, New York.

Newman, Richard L., Chief Engineer to the Globe Iron Works Co.....Cleveland, Ohio.
Nystedt, Thure, Naval Constructor, Royal Swedish Navy, Ingeniör Departament, Carlskrona, Sweden.
Palmer, Nicholas F., Quintard Iron Works.....742 East 12th street, New York.

Pankhurst, John F., General Manager The Globe Iron Works Co ....Cleveland, Ohio.
Park, Eugene H., Draughtsman and Engineer, Southern Pacific R. R. & S. S. Co.,
Algiers (New Orleans), La.
Parsons, H. DeB., Mechanical Engineer..... .....22 William street, New York.
Pearson, F. S., Chief Engineer Metropolitan Traction Co.....621 Broadway, New York.
Pell, Harry S., Superintendent The Stirling Co., Water Tube Safety Boilers.....Barberton, Ohio.
Pray, Thomas, Jr., Consulting Engineer and Electrician.....P. O. Box 2728, Boston, Mass.

Quintard, Geo. W., Quintard Iron Works..... .....12th street and Avenue D, New York.

Raynal, Alfred H., General Superintendent Corliss Steam Engine Co.,
11 Creighton St., Providence, R. I.
Robinson, Edward P., Superintendent The Atlantic Works.....70 Border St., East Boston, Mass.
Rowland, Jonathan, Vice-President, Morris, Tasker & Co.....224 S. 3d street, Philadelphia, Pa.
Rowland, Thomas F., Jr., Secretary and Treasurer, The Continental Iron Works, Brooklyn, N. Y.
Rousseau, David, Proprietor Rousseau Electrical Works.....310 Mott avenue, New York.
Rozycki, L. O. Stephen, Draughtsman, Bureau of Steam Engineering.....Navy Department.

Sanderson, R. P. C., Superintendent Motive Power, West General Division,
Norfolk and Western Railroad, Roanoke, Va.
Schwartz, E. G., Chief Engineer, U. S. R. C. S.. .....Steamer *Dallas*, Boston, Mass
Scott, Irving M., Vice-President and General Manager, Union Iron Works.....San Francisco, Cal.
Scout, Morris C., Chief Engineer, S. S. *Caracas*, Red D Line.....483 Lexington Ave., Brooklyn.
See, Horace, Marine Engineer and Naval Architect.....1 Broadway, New York.
Seabury, Charles L...... Nyack-on-Hudson, N. Y.
Severns, J. A., Chief Engineer, U. S. R. C. S.....1802 Jefferson street, Philadelphia.
Shaw, T. Jackson, Superintending Engineer, The Harlan & Hollingsworth Co., Wilmington, Del.
Sillen, Hillmer Fr., Chief Draughtsman Göteborg's Mek. Verkstad.....Göteborg, Sweden.
Sims, Gardiner C., General Manager Armington & Sims Engine Co.....Providence, R. I.
Slayton, H. O., 1st Assistant Engineer U. S. R. C. S.....Steamer *Orwin*, Port Townsend, Wash.
Sloan, Robert S., President Fitzgibbons Boiler Co.....Oswego, N. Y.
Smith, Charles R., Marine Engineer..... .....19 Woodrow Road, Pollokshields, Glasgow.
Sowter, J. G., Mechanical Engineer.....867 East Congress street, Detroit, Mich.
Spiers, James, President and Manager Fulton Engineering and Shipbuilding Works,
San Francisco, Cal.
Sprague, Wilson, Chief Draughtsman Portland Co.'s Works..... .....Portland, Maine.
Steele, David, Marine Surveyor.....Kemble Building, 15 Whitehall street, New York.
Steers, Henry, Naval Architect ....Eleventh Ward Bank, New York.
Stephens, W. P., Yachting Editor of "Forest and Stream,".....742 Avenue A, Bayonne, N. J.
Stevens, E. A., President Hoboken Ferry Co..... .....Hoboken, N. J.
Stivers, W. D., Assistant Superintendent Quintard Iron Works,
residence, 133 Glenwood avenue, Jersey City, N. J.
Stuart, Sinclair, Surveyor to the U. S. Standard Register of Shipping,
Post Building, 16 Exchange Place, New York.
Sturtevant, Thos. L......Quincy, Mass.
Syme, Jas., Fairfield Works .....Govan, Glasgow, Scotland.

Tabor, Harris, Superintendent Tabor Manufacturing Co.,
Front and Franklin streets, Elizabeth, N. J.; residence, 21 Elm street, Elizabeth, N. J.
Taylor, Cephas..... .....The Linden Steel Co., Pittsburgh, Pa.
Taylor, Stevenson, Vice-President and General Superintendent W. & A. Fletcher Co.,
Hudson, 12th to 14th streets, Hoboken, N. J.
Tromp, Capt A...... .....P. O. Box 373, Rotterdam, Holland.
Tucker, Edwin W., Mechanical Engineer.....818 Page street, San Francisco, Cal.

Uhler, George, President National Marine Engineers' Beneficial Association of the U. S.;
residence, 1609 Brown street, Philadelphia, Pa.

Varney, William W., Mechanical Engineer and Attorney-at-Law,
1001 Harlem avenue, Baltimore, Md.
Volz, Wm. E......39 Cortlandt street, New York.
Voss, Ernest, Marine Engineer, Blohm & Voss, Shipbuilders and Engineers, Hamburg, Germany.

Wachsmann, Wm......Bureau Steam Engineering, Navy Department.
Wadagaki, Yasuzo, Mechanical Engineer.....Imperial Dockyard, Yokosuka, Japan.
Ward, Charles, Engineer and Contractor, Manufacturer Ward Boiler,
Charleston, Kanawha County, W. Va.
Warrington, James N.....127 Park avenue, Chicago, Ill.
Waterhouse, Wm. E., Naval Architect.....50 State street, Boston, Mass.
Wheeler, F. Meriam, Secretary The George F. Blake Manufacturing Co.,
95 and 97 Liberty street, New York.
Whiting, S. B., General Manager Calumet and Hecla Mining Co.....Calumet, L. S., Mich.
Wintringham, H. C., Naval Architect and Engineer,
Room 1205, Havemeyer Building, Cortlandt street, New York.

Yarrow, A. F., Naval Architect and Mechanical Engineer.....Isle of Dogs, Poplar, London.

EXCHANGES.

American Engineer and Railroad Journal.....47 Cedar street, New York.
American Machinist.....168 Fulton street, New York.
American Shipbuilder.....7 Coenties Slip, New York.
American Society of Mechanical Engineers.....12 West 31st street, New York.
Army and Navy Journal.....240 Broadway, New York.
Army and Navy Register.....National Theater Building, Washington, D. C.

Canadian Military Gazette.....P. O. Box 387, Montreal, Canada.
Cassier's Magazine.....Potter Building, New York.

Eastern Guardsman.....100 South Tenth Street, Philadelphia.
Engineering.....35 Bedford street, Strand, London, England.
Engineer (The).....106 Fulton street, New York.
Engineering Magazine.....No. 47 Times Building, New York.
Engineer's Gazette.....Newcastle-upon-Tyne, England.

Forest and Stream.....318 Broadway, New York.
Franklin Institute.....Philadelphia, Pa.

Institution of Civil Engineers,
(Temporary No. 9), 25 Great George street, Westminster, London, S. W., England.

Journal of the United States Artillery.....Fort Monroe, Va.

Literary Digest.....30 Lafayette Place, New York.

Marine Journal.....24 State street, New York.
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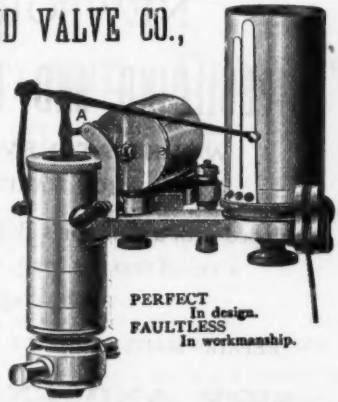

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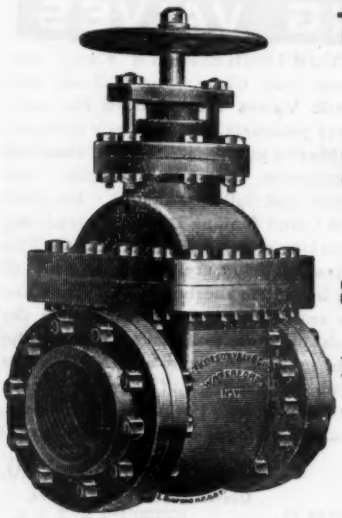

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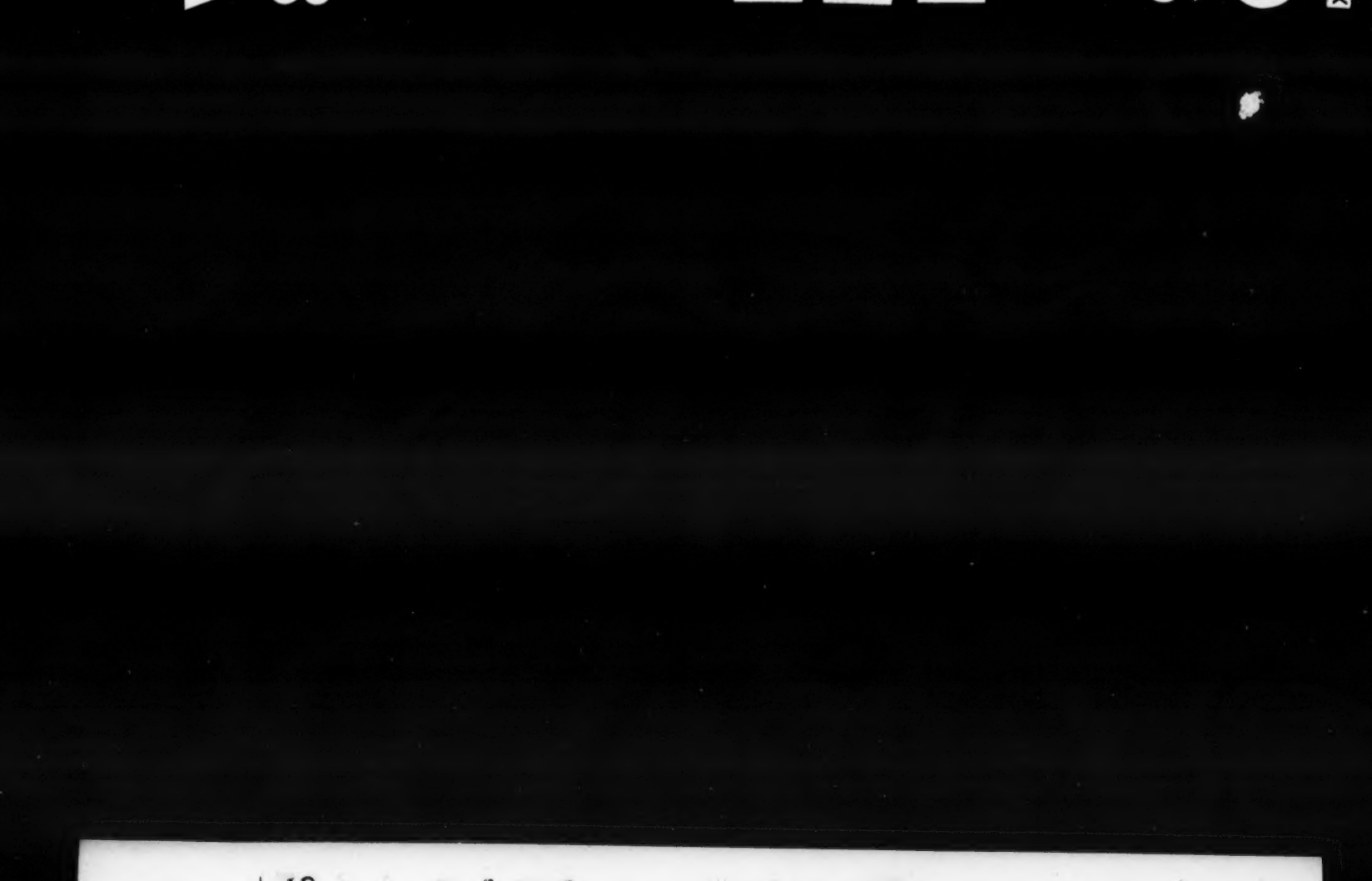

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